Atmosphere Discipline Team 2-page Summaries from TASNPP 2017 PIs

Nov. 2020

<u>Algorithms</u>

Aerosols

1. Christina Hsu
2. Rob Levy

Clouds

3. Steve Ackerman, Rich Frey
4. Andy Heidinger
5. Steve Platnick, Kerry Meyer

Other

6. Brian Baum
7. Eva Borbas
8. Vince Realmuto

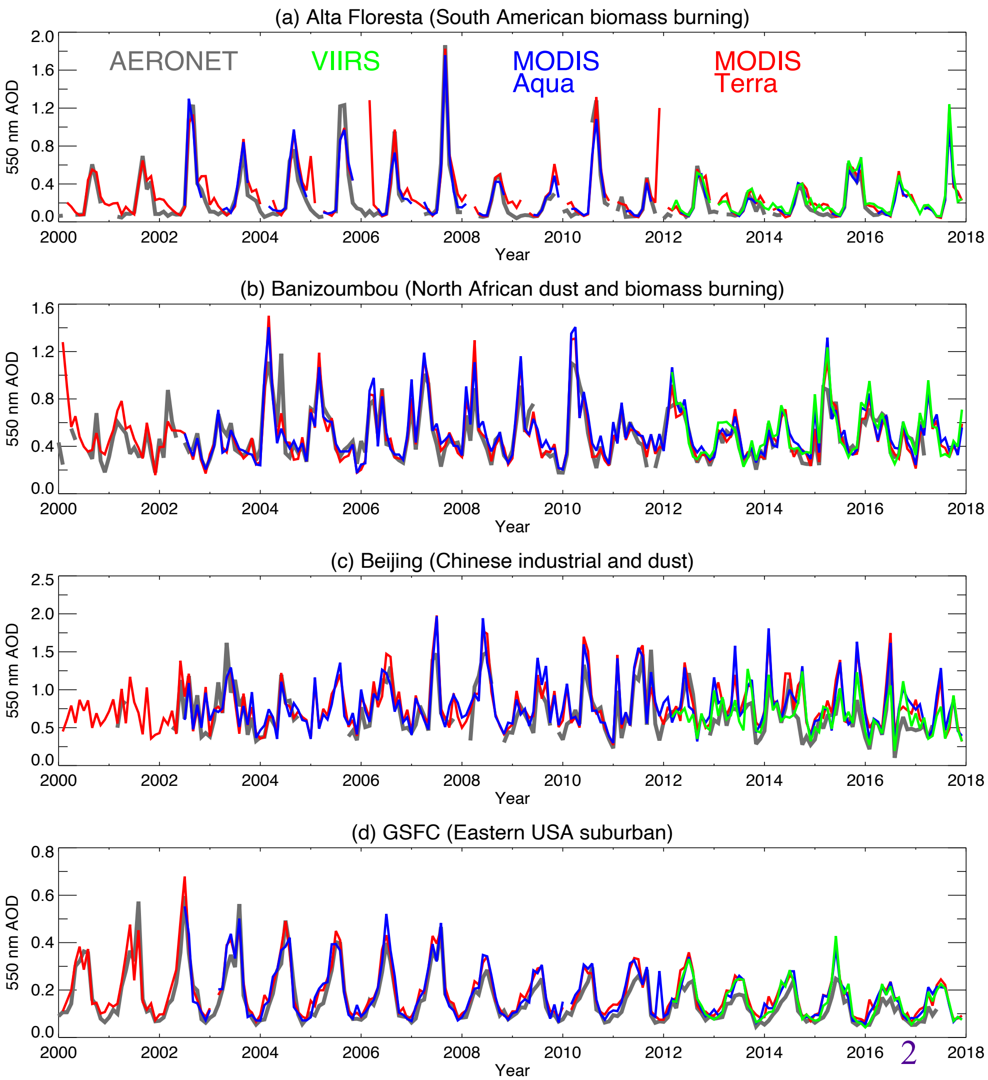
<u>Science Analysis</u>

9. Anthony Davis
10. Qiang Fu
11. Yu Gu
12. Pawan Gupta
13. Jay Mace
14. Tamas Varnai
15. Zhien Wang
16. Eric Wilcox
17. Ping Yang
18. Hongbin Yu, Zhibo Zhang

Multi-Sensor Long-Term Deep Blue Aerosol Products

N. Christina Hsu (PI), Jaehwa Lee, Vincent Kim, and William Heinson

Climate and Radiation Laboratory, NASA Goddard Space Flight Center, Maryland, USA



- *Science Objectives*:

- Our primary goal is to produce consistent long-term aerosol climate data record using multiple satellite sensor data from AVHRR (historic) to SeaWiFS and MODIS (EOS-era) to VIIRS (JPSS-era) as well as latest GEO sensors (such as AHI and ABI) for diurnal cycle.

- Left Panel: This comparison shows multi-year (2002-2018) quantitative consistency of the VIIRS Deep Blue AOD in comparison with our heritage MODIS and SeaWiFS results, as well as AERONET validation data.
  These VIIRS AOD data are generated using corrected VIIRS L1B files after we assessed the calibration of S-NPP VIIRS against MODIS Aqua and developed a cross-calibration correction for VIIRS, which was shown to decrease the uncertainty in retrieved AOD and make VIIRS results more comparable to MODIS.

Multi-Sensor Long-Term Deep Blue Aerosol Products

➢ *Status and updates of the VIIRS/MODIS Deep Blue aerosol products*:

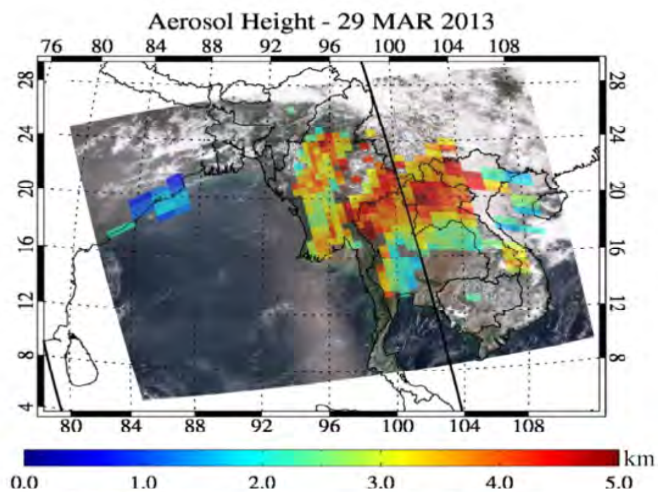
✓ Standard VIIRS L2 and L3 Version 1.0 Deep Blue products have been operational and available at LAADS since late 2018.

✓ NRT VIIRS Deep Blue products also officially became operational in 2019 via LANCE. The imagery is now available at Worldview.

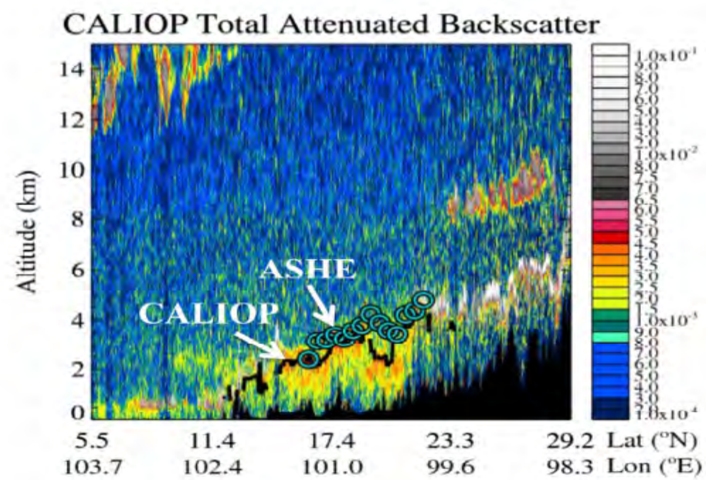
✓ VIIRS Version 1.1 Deep Blue algorithm is finalized and the products will be processed at SIPS soon. Compared to V1.0, the changes made in V1.1 include the improvement of AOD retrieval during the extreme fire events and a few minor bug fixes.

✓ Preparation of implementing new aerosol product retrieval such as aerosol height (shown in right panel) and AOD retrieval over cloud in the VIIRS V2.0 algorithm has started.

✓ Efforts of backporting all the improvements made in VIIRS to MODIS Collection 7 are also underway.



Top: New Deep Blue aerosol height product using ASHE algorithm over Southeast Asia, superimposed on VIIRS true-color image



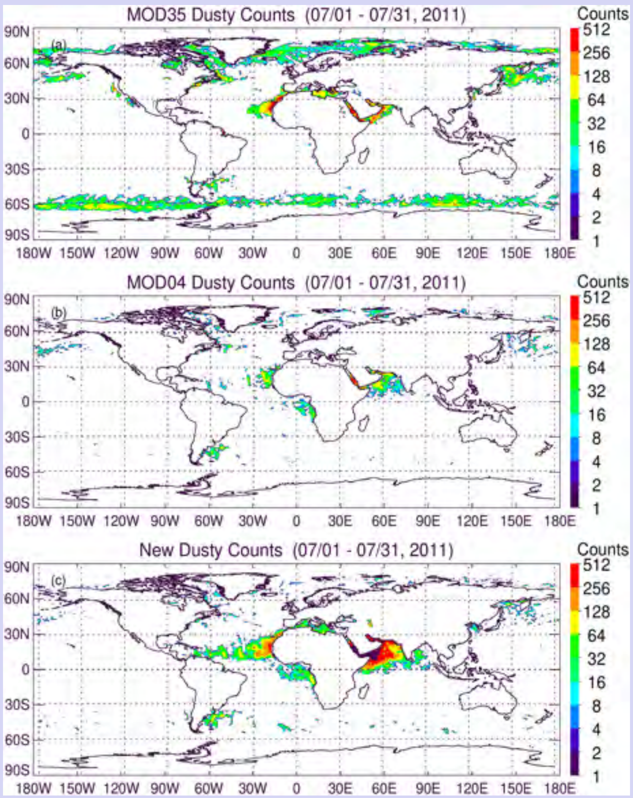
Bottom: Aerosol height from ASHE (green circles) and CALIOP (black lines), superimposed on CALIOP attenuated backscatter

Recent Publication: Lee, *et al.*, 2020, Aerosol layer height with enhanced spectral coverage achieved by synergy between VIIRS and OMPS-NM measurements, IEEE Geo. and Remote Sens. Lett., doi: 10.1109/LGRS.2020.2992099.

Update on the Dark-Target aerosol retrieval project

R. Levy[1], S. Mattoo[2], V. Sawyer[2], Y. Zhou[3], Y. Shi[3], M. Kim[4], R. Kleidman[2], P. Gupta[5], Z. Zhang[6], S. Gassó[7], L. Remer[8]
[1]GSFC/613, [2]SSAI/613, [3]UMBC/613, [4]NPP/613, [5]USRA/MSFC, [6]ADNET/610, [7]ESSIC/613, [8]JCET/UMBC

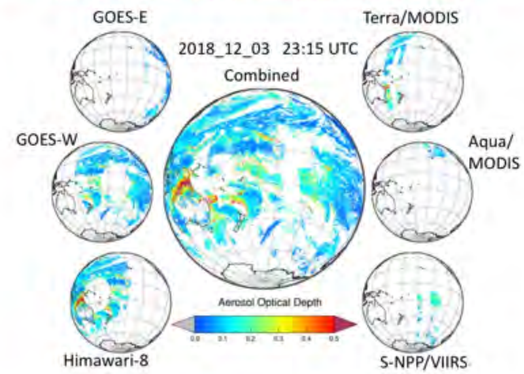
Non-spherical Dust



Zhou, Y. et al., 2020. "Dust Aerosol Retrieval Over the Oceans With the MODIS/VIIRS Dark-Target Algorithm: 1. Dust Detection." *Earth and Space Science:* [10.1029/2020ea001221]

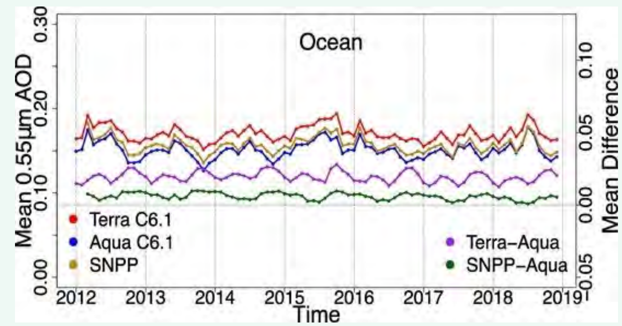
20-Years and Path Forward

During the 1990s, the Dark Target aerosol algorithm was developed for MODIS.
Today it is applied to a constellation of satellite sensors.



Remer, L.A. et al., 2020. "The Dark Target Algorithm for Observing the Global Aerosol System: Past, Present, and Future." *Remote Sensing*, [10.3390/rs12182900]

From MODIS to VIIRS



Sawyer, V., et al., 2020. "Continuing the MODIS Dark Target Aerosol Time Series with VIIRS." *Remote Sensing*, [10.3390/rs12020308]

ALSO

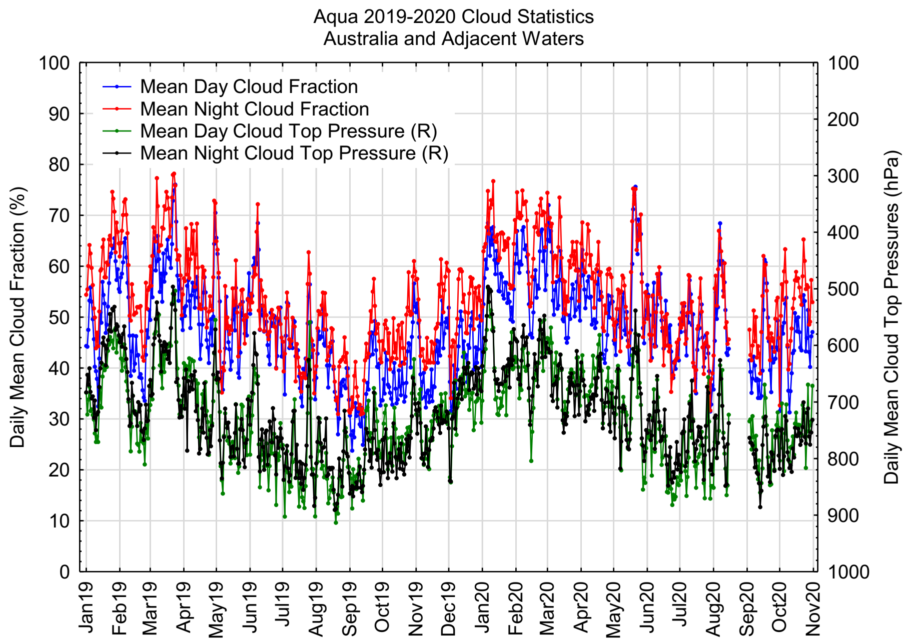
- Zhou, Y., et al. 2020. "Dust Aerosol Retrieval Over the Oceans With the MODIS/VIIRS Dark Target Algorithm: 2. Nonspherical Dust Model." *Earth and Space Science*, [10.1029/2020ea001222]
- Gupta, P., et al., 2020. "High-Resolution Gridded Level 3 Aerosol Optical Depth Data from MODIS." *Remote Sensing*, **12 (17):** 2847 [10.3390/rs12172847]
- Hammer, M. S., et al., 2020. "Global Estimates and Long-Term Trends of Fine Particulate Matter Concentrations (1998–2018)." *Environmental Science & Technology*, [10.1021/acs.est.0c01764]
- Sogacheva, L., et al., 2020. "Merging regional and global aerosol optical depth records from major available satellite products." *Atmos. Chem. Phys*, [10.5194/acp-20-2031-2020]
- Yu, H., et al., 2020. "Interannual variability and trends of combustion aerosol and dust in major continental outflows revealed by MODIS retrievals and CAM5 simulations during 2003–2017." *Atmos. Chem. Phys*, [10.5194/acp-20-139-2020]
- Gupta, P., et al. 2019. "Retrieval of aerosols over Asia from the Advanced Himawari Imager: Expansion oftemporal coverage of the global Dark Target aerosol product." *Atmos. Meas. Techniques*, [10.5194/amt-12-6557-2019]

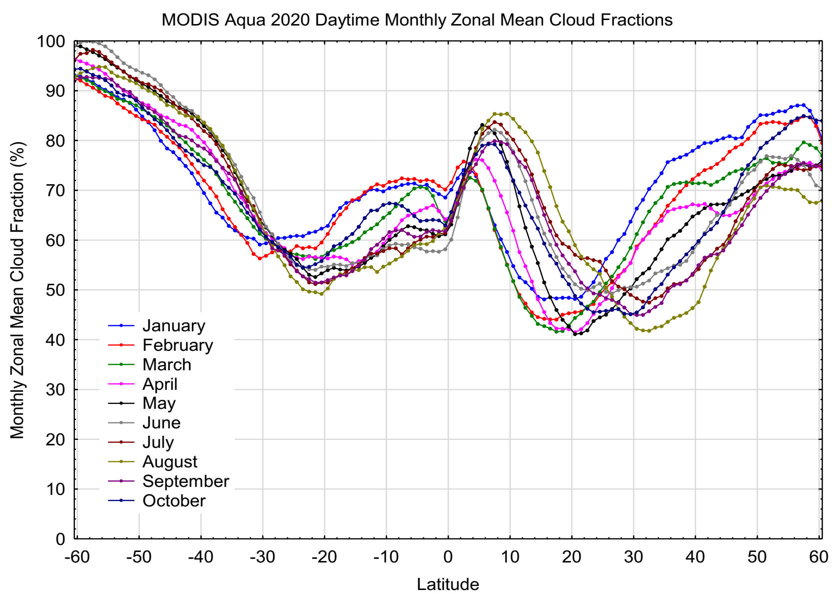
Update on the Dark-Target aerosol retrieval project

- **C6.1 continuing for MODIS with no known new issues**
- **Version 1 running for VIIRS in archive 5110 with 1.1 (bow-tie restoral) in 5111**
- **NRT updated to use GFS forecast at lead of 6 hours if available, 12 hours if not.**
- **Finalize 'the package' (general modular code) that reports in NetCDF** (S. Mattoo)
- **Under Senior Review 'maintenance' we intend to:**
  - Continue validation (Y. Shi)
  - Continue looking at trends (V. Sawyer)
  - Add dust-detection/non spherical dust over ocean (Y. Zhou)
  - Revisit our list of reported SDS's (balance of information versus file size/confusion)
  - Add calculations for 'true' Fine Mode Fraction over land (re-do LUTs)
- **Dark Target "science" in discussion (ROSES?)**
  - Heavy aerosol retrieval over Beijing and other region (Y. Shi)
  - Revisit surface reflectance assumptions (M. Kim)
  - Revisit spatial variability structure for cloud/surface masking (R. Kleidman)
  - Include uncertainties (Jacobians, ensemble, error propagation, etc.)
- **Collaborative science (leveraging other work)**
  - Integrate with GEO imagers (my MEaSUREs project, with P. Gupta)
  - Integrate with Deep Blue (new GEO funding with C. Hsu)
  - Joint UV-VIS/NIR retrieval (e.g. OMPS + VIIRS, led by S. Gassó)
  - Unified UV-VIS-NIR-SWIR retrieval (e.g OCI on PACE, led by L. Remer)

Maintenance of MXD35 and MXD06CT

Steve Ackerman, Rich Frey





Objectives

Maintenance of MXD35 and MXD06CT products

Fix for missing data in MXD06CT L2 granules:
- Cause is negative RH in lowest level of some GDAS profiles
- Delivered to MODAPS; test ordered

Fix for latest update to GDAS files (1-km CTPs via LEOCAT)
- Additional levels of RH and O_3
- Delivered to MODAPS; test ordered

Monitoring of MXD35_L2 and MXD06CT_L2

Top fig.: time series of area daily mean cloud fractions (LHS) and cloud top pressures (RHS)
Bottom fig.: monthly zonal mean cloud fractions for January through October 2020 showing expected seasonal cloud changes

MODIS-VIIRS Cloud Mask (MVCM)

Steve Ackerman, Rich Frey

Status and Updates:

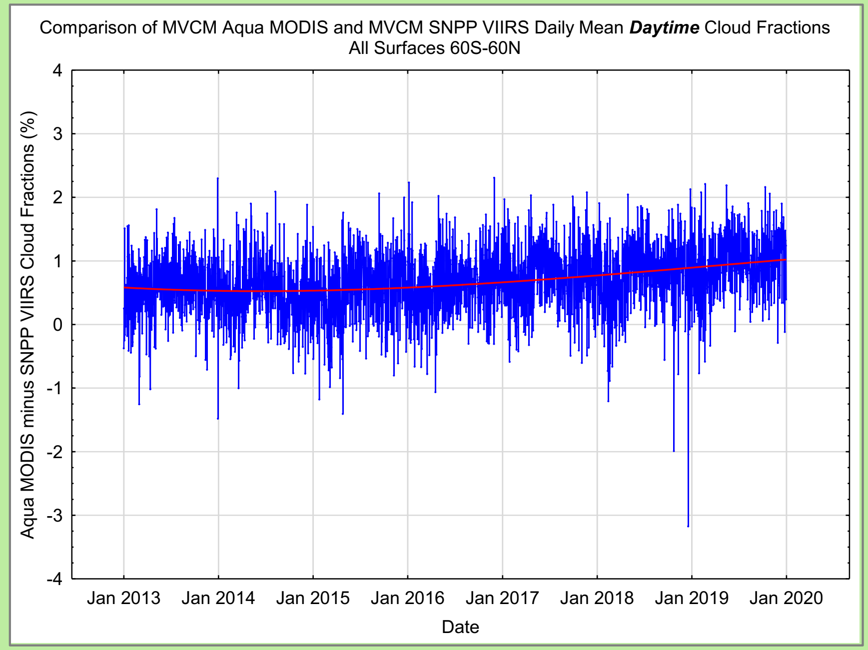
- Aqua MODIS and SNPP VIIRS available at the Goddard DAAC; NOAA-20 VIIRS soon
- Additional algorithm development in progress

Known Issues:

- Cloud detection threshold updates needed (polar)
- VNIR calibration offsets between Aqua MODIS AND SNPP VIIRS

Recent Publications:

The Continuity MODIS-VIIRS Cloud Mask: R. Frey, S. Ackerman, R. Holz, S. Dutcher, Z. Griffith, *Remote Sensing*, 13 October 2020

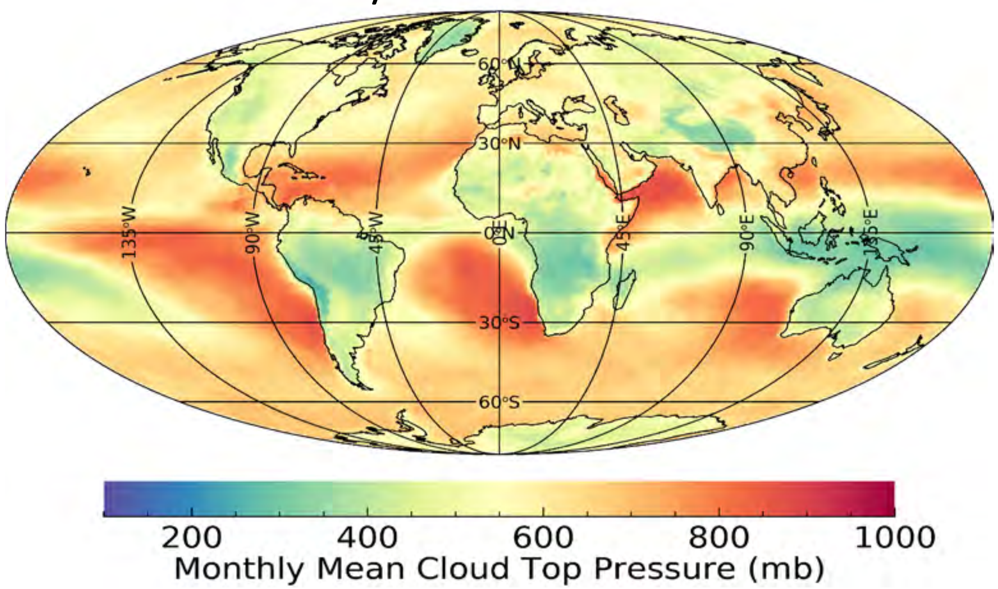


Plot above shows Aqua MODIS daytime cloud fractions increasing by ~0.5% relative to SNPP VIIRS from 2013 through 2019.

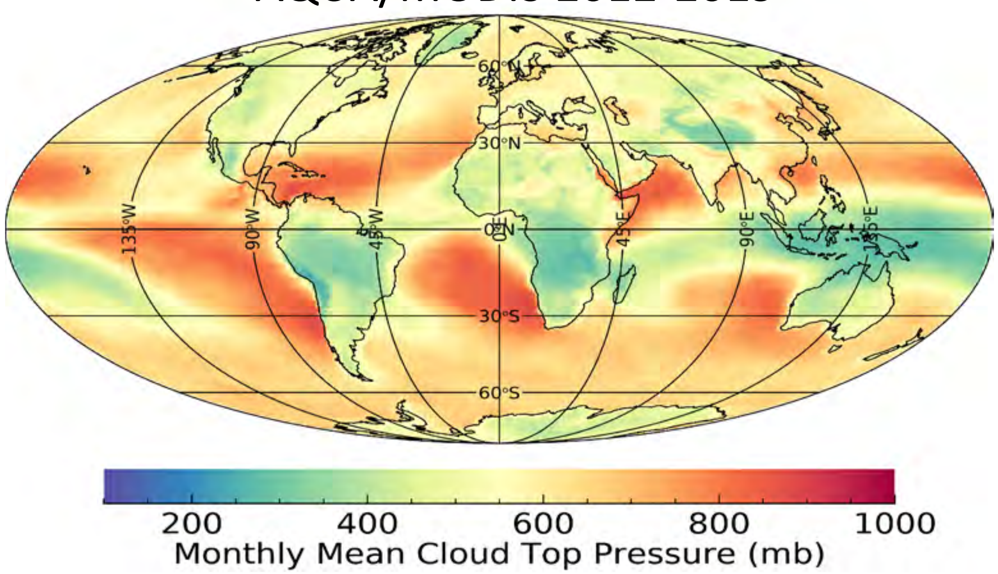
MODIS/VIIRS Continuity IR Cloud Properties (IR CLDPROP)

Andrew Heidinger (NOAA), Yue Li, Paolo Veglio (CIMSS)

SNPP/VIIRS 2012-2019



AQUA/MODIS 2012-2019



The goal of the IR CLDPROP is generate a record of cloud macrophysical properties (**cloud top temp-press-height**) and microphysical properties (**phase**, **emissivity,** optical depth, particle size) using the shared InfraRed (IR) observations from MODIS and VIIRS.

VIIRS has fewer IR observations than MODIS and the traditional CO_2 slicing approach used in MYD06 can't run on VIIRS. VIIRS IR data forces use of an Optimal Estimation (O.E.) IR algorithm that uses window channels which allow us to simultaneously retrieve microphysical information.

We are pursuing synergistic use of the CrIS spectra with VIIRS allow for a better spectral baseline with MODIS through fusion and use of the CrIS hyperspectral products to improve the IR-CLDPROP values for semi transparent ice clouds.

MODIS/VIIRS Continuity IR Cloud Properties (IR CLDPROP) Andrew Heidinger (NOAA), Yue Li, Paolo Veglio (CIMSS)

Status and Updates:

- IR CLDPROP modified for NOAA-20 and Delivered to A-SIPS.
- IR-Phase updated to be probabilistic.

Wanted Products:

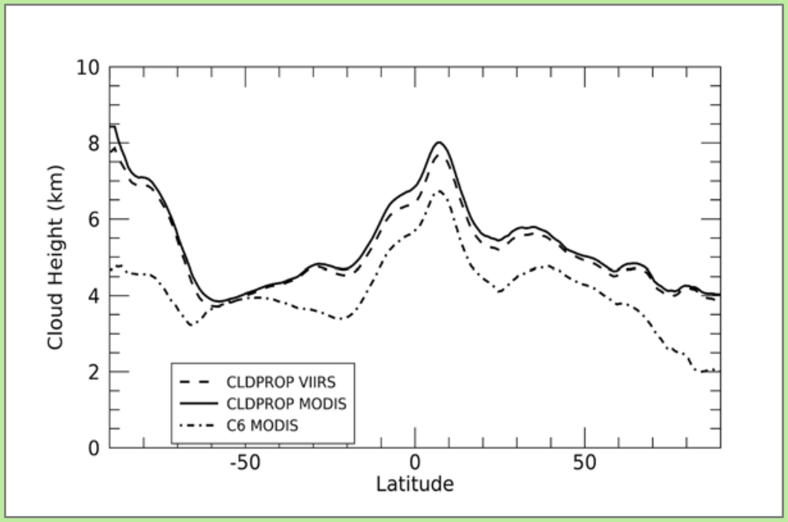
- VIIRS/CrIS Fusion for experimentation with CO_2 Slicing on VIIRS to compare with MYD06.
- CrIS Sounder products for a priori values in O.E.

Known Issues:

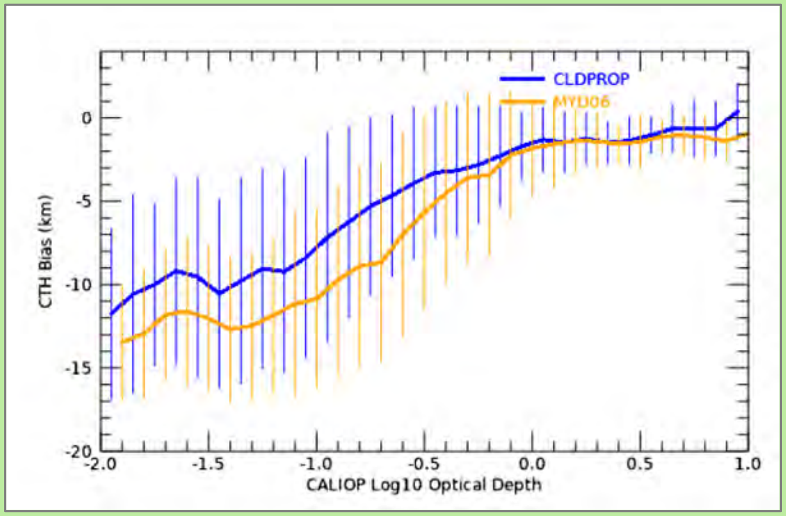
- CLDPROP M3 cloud emissivity in CLDPROP includes clear-sky. MYD08 does not. (my hypothesis)

Recent Publications:

Li, Y., Baum, B. A., Heidinger, A. K., Menzel, W. P., and Weisz, E.: Improvement in cloud retrievals from VIIRS through the use of infrared absorption channels constructed from VIIRS+CrIS data fusion, Atmos. Meas. Tech., 13, 4035–4049, https://doi.org/10.5194/amt-13-4035-2020, 2020.



Zonal mean cloud top height derived using 8 years of monthly mean files from March 2012 to February 2020



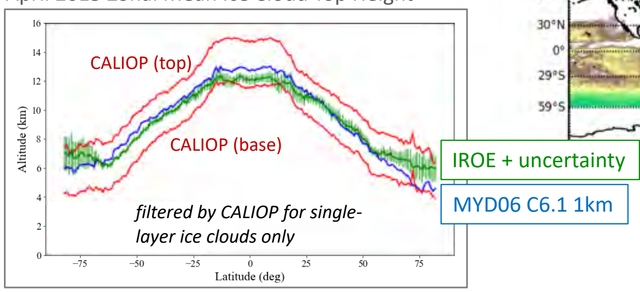
Cloud Height comparison to CALIPSO/CALIOP as a function of CALIOP Optical Depth.

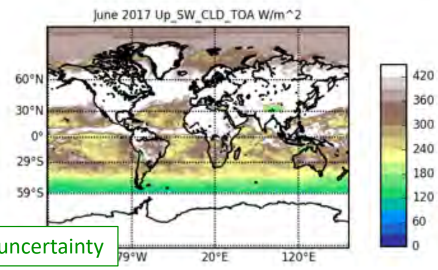
Cloud Optical Properties:
MODIS Standard & MODIS-VIIRS Continuity Products

Platnick, Meyer, Wind, Wang, Amarasinghe, Marchant, Hubanks, Holz, Manoharan, Bhoi, Dutcher, Veglio, Botambekov, Gumley

MODIS Standard C7 Science Testing Examples

April 2015 Zonal Mean Ice Cloud Top Height





Objectives

- To continue maintaining the C6.1 MODIS standard cloud optical property products and to prepare and implement key advancements for C7 reprocessing.
- To continue advancing the common CLDPROP algorithm designed to provide continuity between EOS MODIS and the VIIRS imagers on SNPP and NOAA-20+.

Cloud Continuity Product Paradigm

MODIS Aqua L1B + Geolocation
MYD02, **MYD03**
(channel subset common w/VIIRS)

NASA VIIRS L1B intermediate product*
(w/restored bow-tie pixel deletions + VNIR/SWIR radiometric adjustments) + Geolocation
VNP02MOD, VGEOM

U. Wisconsin A-SIPS processing
Cloud Mask: MOD35 heritage
Cloud-Top: NOAA AWG heritage
Cloud Optical Properties: MOD06 heritage

MODIS Continuity Products
CLDMSK_L2_MODIS_Aqua
CLDPROP_L2_MODIS_Aqua

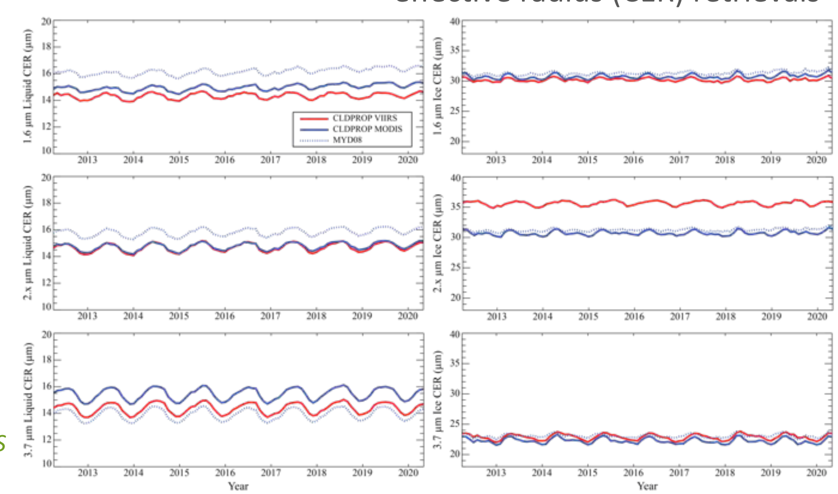
VIIRS Continuity Products
CLDMSK_L2_VIIRS_SNPP
CLDPROP_L2_VIIRS_SNPP

L3 Continuity Products ("Yori")
CLDPROP_D/M3_VIIRS_SNPP
CLDPROP_D/M3_MODIS_Aqua

** Atmosphere SIPS*

CLDPROP Continuity Assessment

Liquid (left) and ice (right) cloud effective radius (CER) retrievals



Cloud Optical Properties: MODIS Standard & MODIS-VIIRS Continuity Products

Platnick, Meyer, Wind, Wang, Amarasinghe, Marchant, Hubanks, Holz, Manoharan, Bhoi, Dutcher, Veglio, Botambekov, Gumley

Status and Updates:

- Several C7 updates in testing; additional product enhancements under evaluation.
- CLDPROP v1.1 processing for NOAA-20 VIIRS begins.
- CLDPROP MODIS-VIIRS continuity evaluation ongoing.

Needed Products:

- MODIS standard: MOD/MYD03, MOD/MYD021KM, MOD/MYD35, MOD/MYD06 CT, various ancillary
- CLDPROP: MYD03, MYD021KM, VNP03_MOD, VNP02_MOD, CLDMSK_MODIS/VIIRS, CLDPROP_MODIS/VIIRS CT, various ancillary

Known Issues:

- See https://atmosphere-imager.gsfc.nasa.gov/issues/cloud for MODIS standard; https://atmosphere-imager.gsfc.nasa.gov/continuity/issues/cldprop_l2 for CLDPROP continuity

Recent Publications:

Meyer, K., S. Platnick, R. Holz, S. Dutcher, G. Quinn, and F. Nagle (2020), Derivation of shortwave radiometric adjustments for SNPP and NOAA-20 VIIRS for the NASA MODIS-VIIRS continuity cloud products, *Rem. Sens.*, submitted

Platnick, S., K. G. Meyer, N. Amarasinghe, G. Wind, P. A. Hubanks, R. E. Holz (2020a), Sensitivity of multispectral imager liquid water cloud microphysical retrievals to the index of refraction, *Rem. Sens.*, submitted.

Platnick, S., K. Meyer, G. Wind, and R. Holz (2020b), The NASA MODIS-VIIRS continuity cloud optical properties products, *Rem. Sens.*, submitted.

- MODIS Standard C7 Updates in Science Testing:
  - Pixel-level radiative flux
  - IR optimal estimation retrievals of cloud-top properties, optical properties
  - 1.38μm cirrus retrievals
  - New MOD08 L3 algorithm
- CLDPROP MODIS-VIIRS Continuity Evaluation
  - Differences in spatial resolution, temporal sampling, angular sampling, etc.
- CFMIP Obs. Sim. Package (COSP) Products
  - Subset of key L3 cloud parameters geared for climate modelers.
  - C6.1 MODIS standard released, v1.1 CLDPROP pending.

Fusion of VIIRS and CrIS data to Construct Supplementary Infrared Band Radiances for VIIRS

Bryan A. Baum (PI, STC), Elisabeth Weisz (SSEC, Co-I), Eva Borbas and Paul Menzel (SSEC)

Objective: To construct MODIS-like infrared (IR) spectral band radiances for VIIRS from merged CrIS and VIIRS data. MODIS has three channels sensitive to CO_2 in the 4.5 μm CO_2 band, four channels in the broad 15 μm CO_2 band, 2 channels sensitive to H_2O near 6.7 μm, and an ozone channel near 9 μm. VIIRS has none of these IR absorption bands. Our Level-2 product provides these IR channel radiances for both S-NPP and NOAA-20 at VIIRS M-band resolution (750m).

Important Results: Improvement in Cloud Heights (left) and Total Precipitable Water Vapor (right)

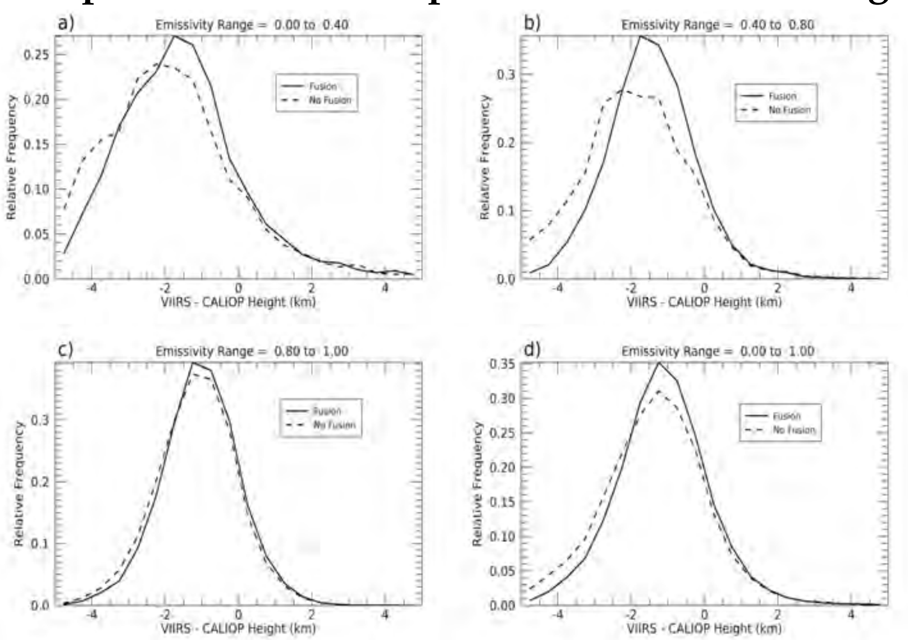


Figure 1: Bias distribution of cloud top height between S-NPP VIIRS and CALIPSO/CALIOP for emissivity range a) 0 to 0.4; b) 0.4 to 0.8; c) 0.8 to 1.0; and d) 0 to 1.0. Solid and dashed lines indicate data with/without fusion channels. Figure taken from Li et al. (2020).

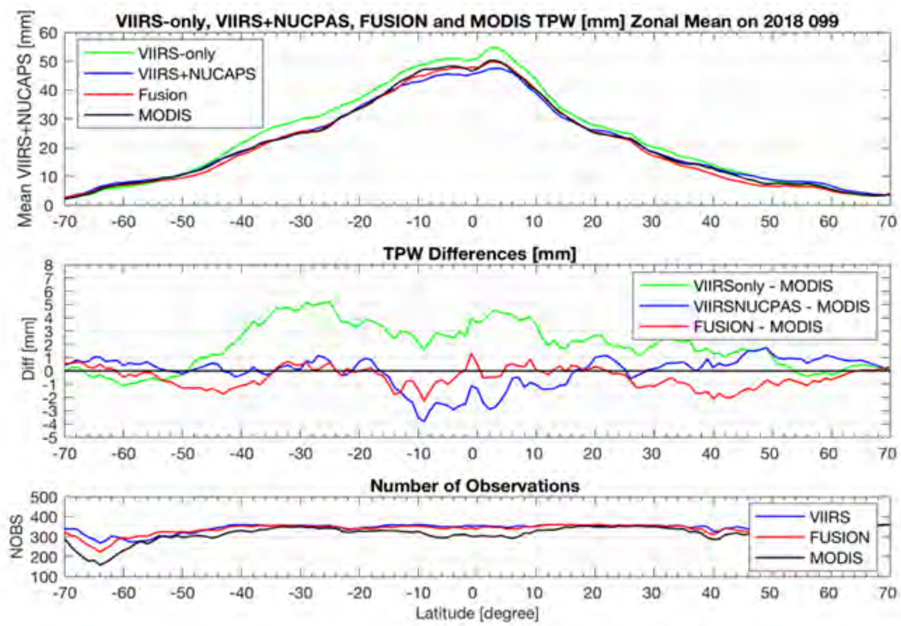


Figure 2. Top: latitudinal distribution of TPW [mm] results for 9 Apr 2018. The middle panel illustrates the corresponding differences while the lowest panel shows the number of observations in each 1° latitude bin.

Fusion of VIIRS and CrIS data to Construct Supplementary Infrared Band Radiances for VIIRS

Bryan A. Baum (PI, STC), Elisabeth Weisz (SSEC, Co-I), Eva Borbas and Paul Menzel (SSEC)

Status and Updates:

- V1.01 fusion radiance product available for entire record of both S-NPP and NOAA-20
- Software updated and in review at A-SIPS; next version of fusion radiances will soon be in production. Yield will be improved (currently > 98% for S-NPP; 99.9% for NOAA-20)
- Working with CERES team to implement NOAA-20 fusion product

Needed Products: VIIRS/CrIS L1-b data

Known Issues: H_2O fusion band radiances have slight surface artifacts in very dry regions

Recent Publications:

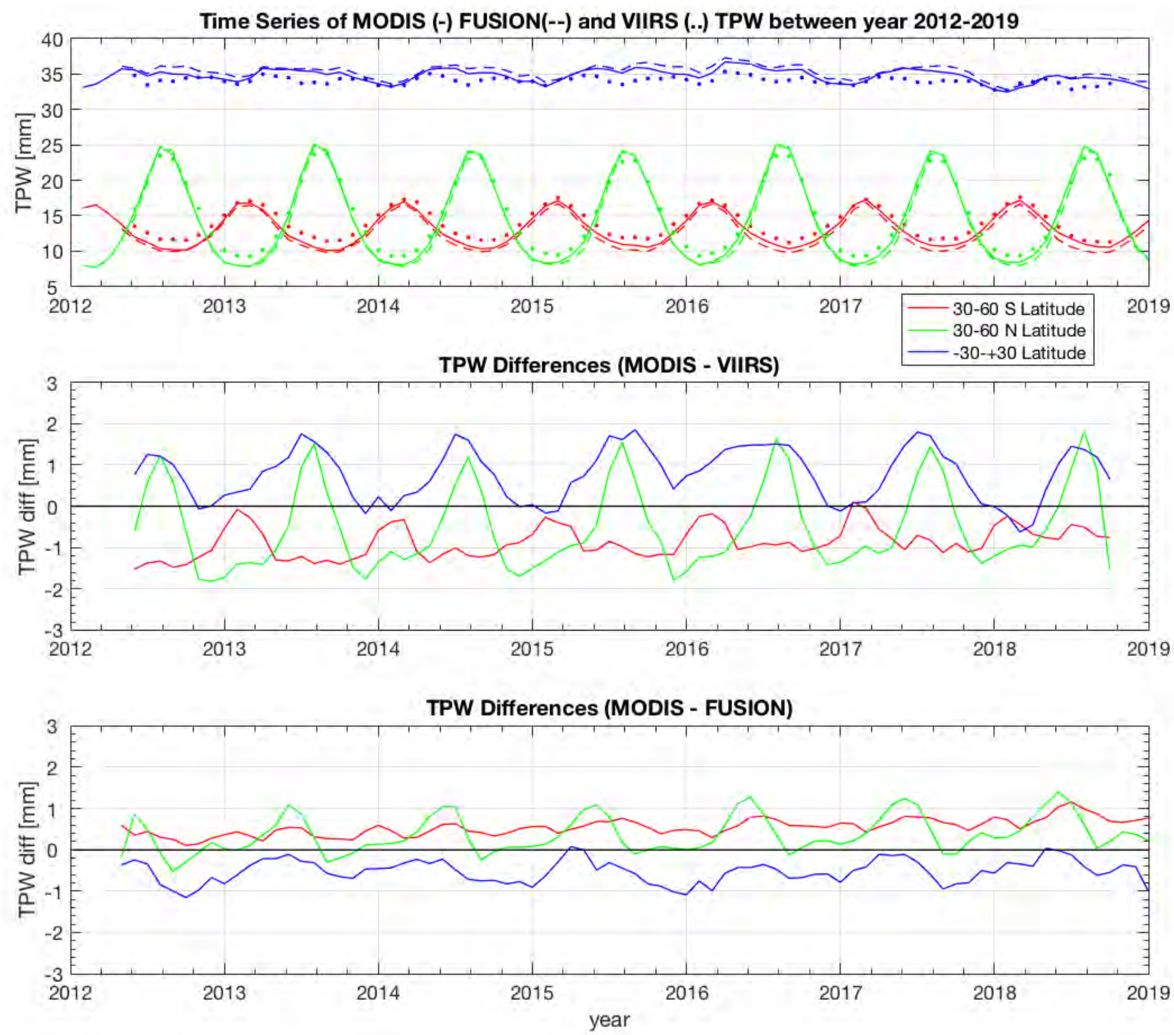
- Borbas, E. E., E. Weisz, C. Moeller, W. P. Menzel, and B. A. Baum: Improvement in tropospheric moisture retrievals from VIIRS through the use of infrared absorption bands constructed from VIIRS and CrIS data fusion. In review, *Atmos. Meas. Tech. Disc.*, in review, 2020.
- Li, Y., Baum, B. A., Heidinger, A. K., Menzel, W. P., and Weisz, E., 2020: Improvement in cloud retrievals from VIIRS through the use of infrared absorption channels constructed from VIIRS-CrIS data fusion, *Atmos. Meas. Tech.*, **13**, 4035-4059.

- Bryan Baum is the S-NPP platform science team leader as well as the PI of this effort
- Our production team is actively working with the CERES team to implement the NOAA-20 fusion product.
- Note that we are providing the fusion product for NOAA-20 although it was not part of our proposed effort.

MOD07 Atmospheric Profile and VIIRS Moisture Retrieval

E. Eva Borbas, Paul Menzel, Steve Ackerman

Objective: To provide high spatial resolution total column water vapor (TPW) from MODIS and VIIRS infrared measurements. Profiles of temperature, water vapor, and ozone as well as stability indexes are also provided from MODIS. While MODIS has two water vapor channels within the 6.5 µm H2O absorption band and four channels within the 15 µm CO2 absorption band, VIIRS has no channels in either IR absorption band. The absence of any IR absorption channels on VIIRS degrades the capability for moisture column products. Our approach for mitigating this deficiency has been to supplement the VIIRS data with products based on the CrIS/ATMS sensors. In the future we plan to use the MODIS-like VIIRS fusion radiances.

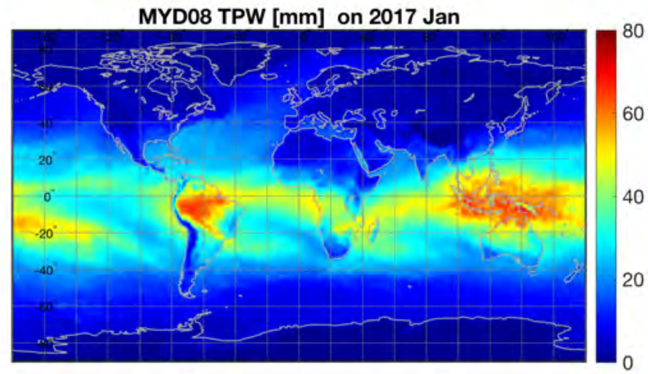


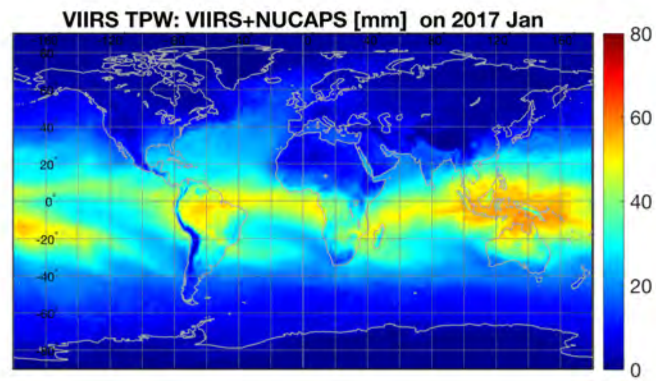
MOD07 Atmospheric Profile and VIIRS Moisture Retrieval

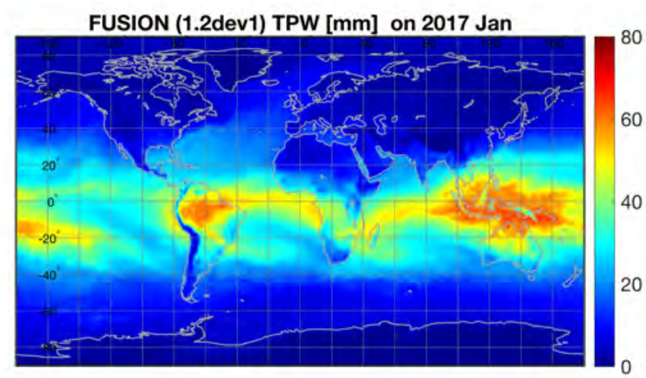
E. Eva Borbas, Paul Menzel, Steve Ackerman

Status and Updates:

- MOD07 preparation for Col7
- S-NPP VIIRS_WATVP V001 is available up to Sept 2018
- VIIRS_WATVP is not currently funded, so no more data was produced.
- VIIRS_VATVP software has been updated (V002) by using fusion radiances; it has been integrated at A-SIPS.
- The new fusion product is planned to be available for the entire record of both S-NPP and NOAA20.







Necessary Ancillary Products:

L1B radiances, Geolocation file, Cloud Mask, NWP analyses

Known Issues:

- **MOD07**: inversion over ice causing instable retrievals in a small area at the Weddell Sea. This will be fixed in Col7.
- **VIIRS_WATVP:** V001 product is available till Sept 2018, because the format of the input data has been changed and there is no funding/support for an update.

Recent Publications:

Borbas, E. E., E. Weisz, C. Moeller, W. P. Menzel, and B. A. Baum: Improvement in tropospheric moisture retrievals from VIIRS through the use of infrared absorption bands constructed from VIIRS and CrIS data fusion. *Atmos. Meas. Tech.*, in review, 2020.

Thermal Infrared (TIR) Remote Sensing of Volcanic Plumes with MODIS and VIIRS

Vincent J. Realmuto

16 November 2020

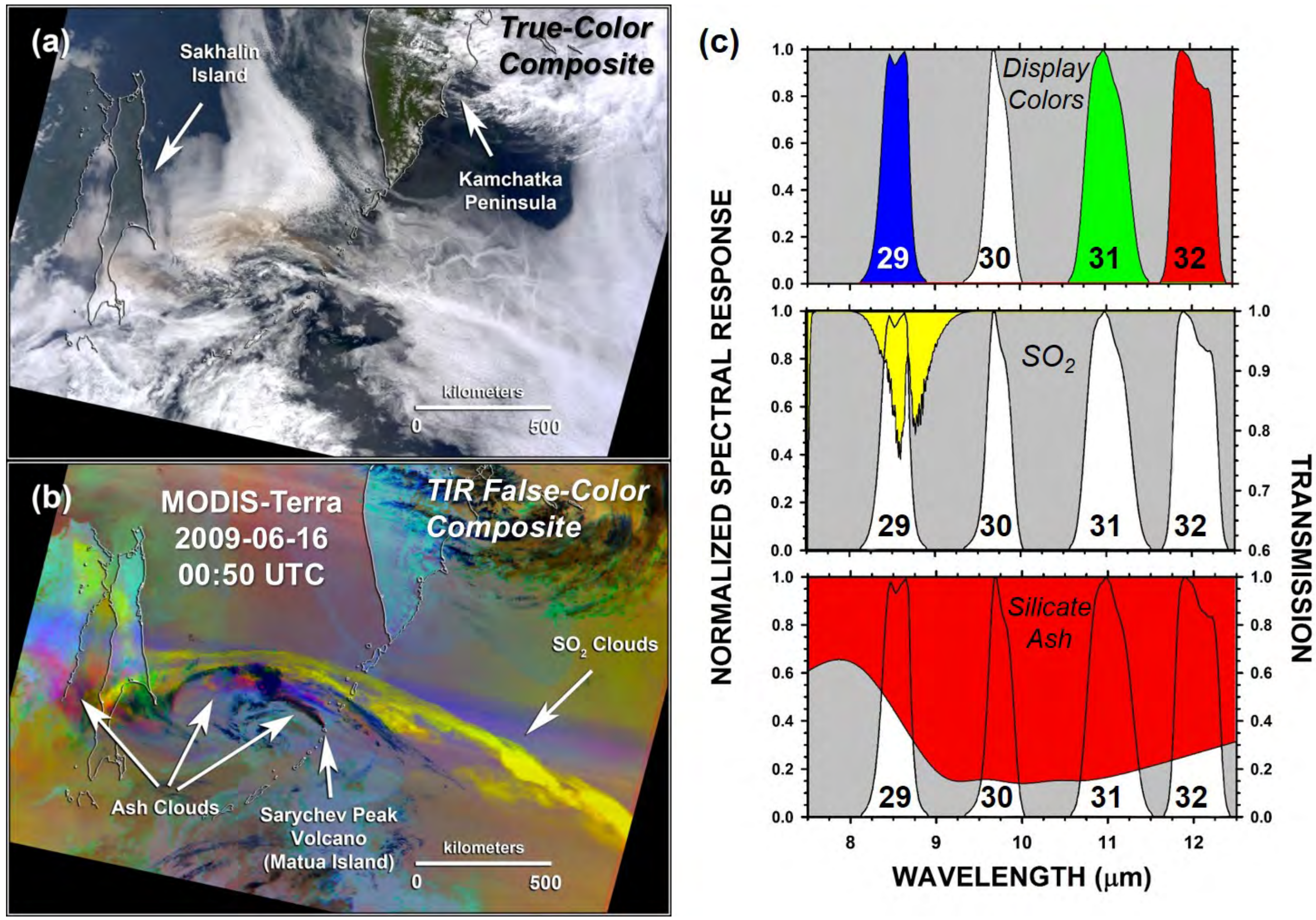
Plume Spectroscopy: Sarychev Peak Volcano

Jet Propulsion Laboratory
California Institute of Technology

a) MODIS-Terra True-color composite. Volcanic plumes and meteorological clouds have similar appearance at visible wavelengths

b) False-color composite of TIR data from Channels 32, 31, and 29, displayed in red, green, and blue. SO_2 plumes appear yellow, while the display colors of ash plumes range between red and magenta

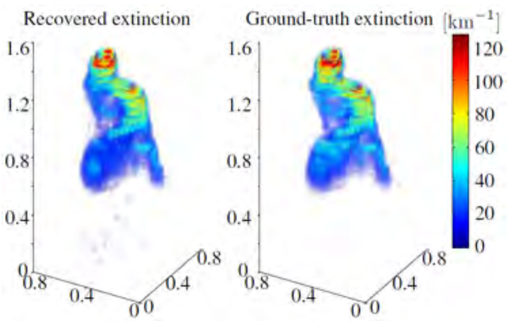
c) Transmission spectra of SO_2 (middle) and silicate ash (bottom), superimposed on the spectral response of MODIS Channels 29, 30, 31, and 32



Addressing cloud-related climate challenges with LES cloud-process models, data from MISR and MODIS, novel reconstruction techniques for 3D convective clouds

Anthony B. Davis [PI] & Linda Forster (JPL/Caltech), and Aviad Levis (Caltech/CMS)

Practical 3D cloud tomography (CT) was demonstrated by Levis et al. [2015, 2017] on both LES and real-world clouds with both gridcell and image pixel scales ~20 m, which are *optically thin* in general.

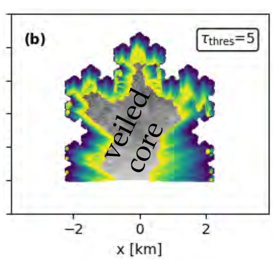


JPL Large Eddy Simulation model:
RICO scenario

9 MISR-type views:
±70.5°,±60.0°,±45.6°,±26.1°,0°

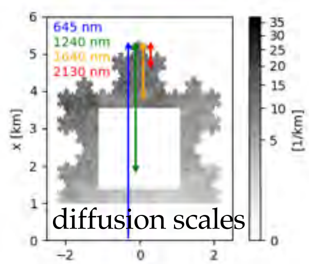
Extinction grid:
46,656 unknowns

The present TASNPP project is to adapt that tomographic method to multi-angle/multi-spectral imaging from space (i.e., MISR+MODIS/Terra) where pixels are ~250 m, which can translate to *optically thick* cloud elements, thus raising significant issues for both forward modeling and inversion techniques.



← veiled core (VC) at optical depths >5 to sun & sensors: Details inside don't matter for CT!

VC is bigger for MODIS SWIR channels due to absorption →



The notion of "veiled cores" in opaque 3D convective clouds helps to overcome both kinds of issue in CT from space.

OBJECTIVES

- Develop a ***practical* 3D generalization of the bi-spectral (a.k.a. Nakajima–King) 1D operational algorithm** for **MODIS** cloud property retrievals that is applicable to vertically-developed 3D cumulus clouds using a new tomographic methodology, and fusing with **MISR** data.
- Use Large-Eddy Simulation (LES) cloud fields and high-fidelity 3D radiative transfer (RT) to **synthesize MISR and MODIS data with known ground truth** for various convective scenarios.
- **Quantify retrieval error** in the 3D macro- and micro-physical cloud reconstructions using the synthetic MISR+MODIS data.
- Process **real-world MISR+MODIS data for clouds** observed in-situ and with airborne sensors **during field campaigns of opportunity**.
- Promote the **new 3D cloud remote sensing capability** within certain defined stakeholder communities of cloud-process modelers and atmospheric scientists in the parameterization of **cloud-aerosol-climate interactions**.

Addressing cloud-related climate challenges with LES cloud-process models, data from MISR and MODIS, novel reconstruction techniques for 3D convective clouds

Anthony B. Davis [PI] & Linda Forster (JPL/Caltech), and Aviad Levis (Caltech/CMS)

Status and Updates:

- Main computational challenges stemming from the (larger-than-airborne) size of MISR and MODIS pixels have been identified and documented in the literature.
- Cloud tomography algorithm adaptations and extensions (including machine-learning) have been explored using LES modeling and real-world testbeds.
- Space-based cloud tomography research network is established.

Needed Products:

- MISR and MODIS L1b radiances
- Selected MISR and MODIS L2 cloud products

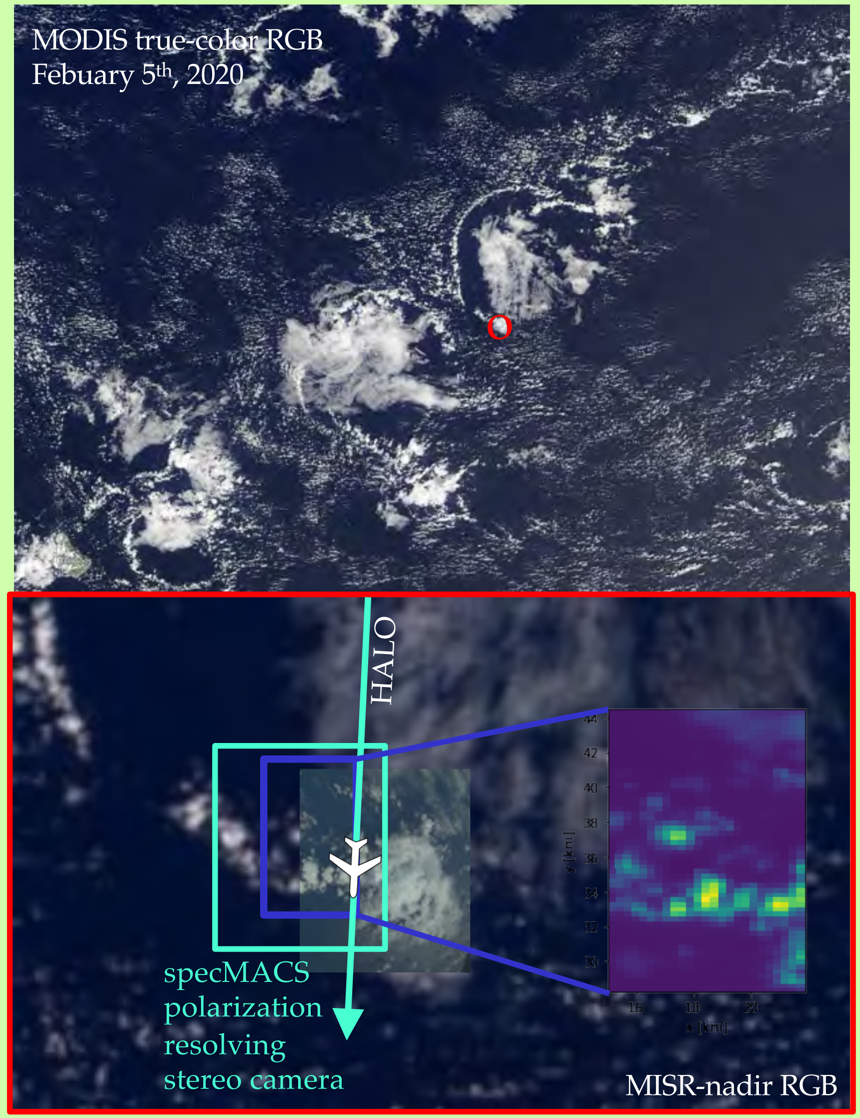
Known Issues:

- N/A

Recent Publications:

- L. Forster, A. B. Davis, B. Mayer, and D. J. Diner (2020), Toward Convective Cloud Tomography from Space using MISR and MODIS: Locating the "Veiled Core" in Opaque Convective Clouds, *J. Atmos. Sci.* (in press). http://arxiv.org/abs/1910.00077
- A. Levis, Y. Y. Schechner, A. B. Davis, and J. Loveridge (2020), Multi-View Polarimetric Scattering Cloud Tomography and Retrieval of Droplet Size. *Remote Sensing*, **12**, 2831– ; as part of Special Issue on "Remote Sensing of Cloud and Aerosol Properties in a Three-Dimensional Atmosphere". https://doi.org/10.3390/rs12172831

EUREC^{4}A (ElUcidating the Role of Clouds-Circulation Coupling in ClimAte) field campaign, Barbados, 1/20-2/20, 2020



The impact of tropical clouds on changes in tropical lower-stratospheric temperatures

Qiang Fu, PI, University of Washington

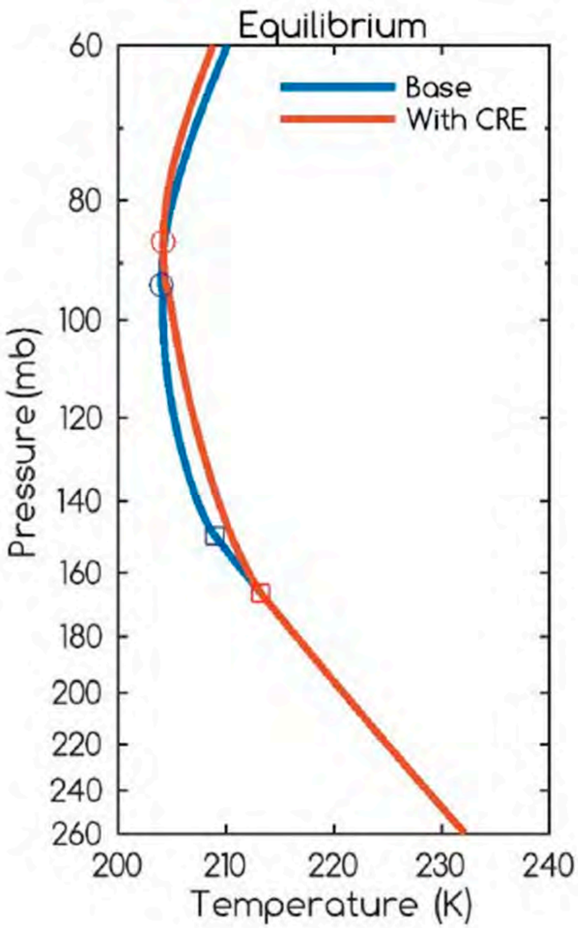


Fig. Equilibrium temperature profiles from the radiative–convective model with (red) and without (blue) cloud radiative effects over the tropics (±20°). The square symbols indicate the top of convection. Circles indicate the cold point.

Objectives: The overall objective of this project is to investigate the dynamically forced changes in tropical lower-stratospheric temperatures through the fusion of Aqua/MODIS and Aura/MLS measurements along with reanalysis data and radiation models. We address the key scientific question that, for a change in tropical lower-stratospheric temperature driven by the upwelling changes there, how much temperature change is directly caused by the upwelling changes, and how much is indirectly brought about through their effect on radiatively active constituents. The proposed project represents the first research effort to take into account cloud radiative effects on the lower-stratospheric temperatures through both cloud climatological backgrounds and cloud changes, achieved though the fusion of the Aqua MODIS and Aura MLS observations with the radiation models.

The impact of tropical clouds on changes in tropical lower-stratospheric temperatures

Qiang Fu, PI, University of Washington

Status and Updates:

- Examine the response of water vapor, ozone, and tropical tropopause layer thin cirrus clouds to the large-scale dynamics

Needed Products:

- MODIS/VIIRS most recent cloud products

Known Issues:

- The differences between the MODIS/VIIRS cirrus optical depths and those from the CALIPSO

Recent Publications:

- Fu, Q., S. Solomon, H. A. Pahlavan, and P. Lin, 2019: Observed changes in Brewer–Dobson circulation for 1980–2018. Environ. Res. Lett., 14, 11, doi:10.1088/1748-9326/ab4de7.
- Steiner, A. K., F. Ladstadter, W. J. Randel, A. C. Maycock, Q. Fu, et al., 2020: Observed Temperature Changes in the Troposphere and Stratosphere from 1979 to 2018. J. Climate, 33, 19, doi:10.1175/JCLI-D-19-0998.1.

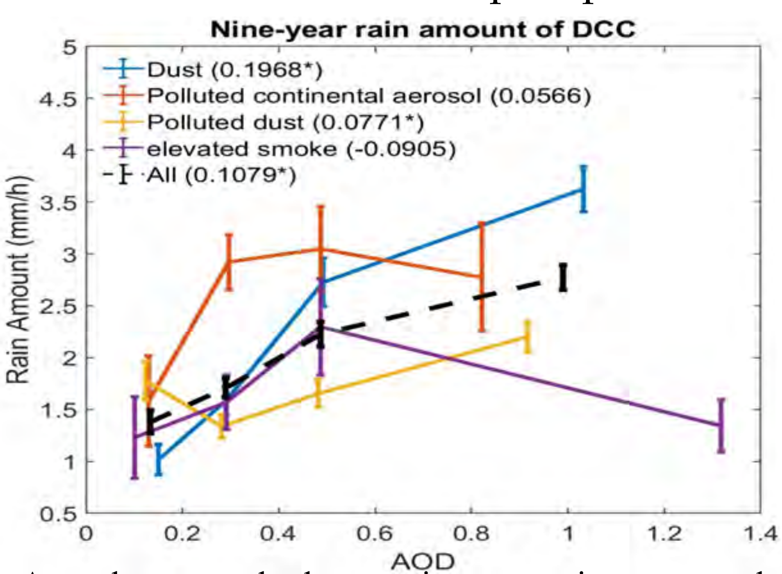
Type-Dependent Impact of Aerosols on Precipitation Associated with Deep Convective Cloud over East Asia

PI: Yu Gu[1] Co-I: Kuo-Nan Liou[1], Bin Zhao[2]

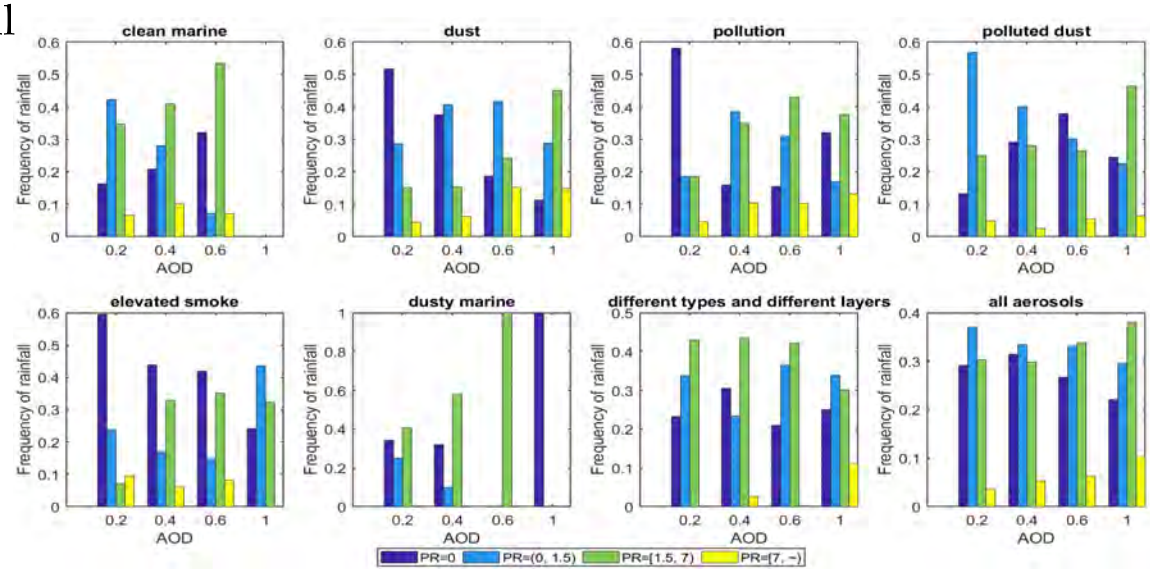
[1]University of California Los Angeles [2]Pacific Northwest National Laboratory

Using 9-year observations from multiple satellite-borne sensors, we find that the frequency of heavy/light rain associated with deep convective clouds increases/decreases with AOD for dust and polluted continental aerosol types. For rain amount, elevated smoke tends to suppress annual mean deep convective precipitation, while dust and polluted continental aerosols enhance overall precipitation.

Objective: This study is to investigate the impact of various types of aerosols on precipitation associated with deep convective clouds using observations from multiple satellites, including MODIS, CALIPSO, and CloudSat.



Annual averaged changes in convection-generated precipitation with AOD for different aerosol types (dust, polluted continental aerosol, polluted dust, and smoke) in East Asia.



Response of precipitation frequency associated with convective clouds to AOD of different aerosol types in East Asia. Precipitation is divided into 4 groups, no/light/moderate/heavy precipitation, according to China Meteorological Agency precipitation intensity standard.

Type-Dependent Impact of Aerosols on Precipitation Associated with Deep Convective Cloud over East Asia

PI: Yu Gu[1] Co-I: Kuo-Nan Liou[1], Bin Zhao[2]

[1]University of California Los Angeles [2]Pacific Northwest National Laboratory

Status:

- Investigated the impact of various types of aerosols on precipitation.
- Elucidated the modulation of the aerosol impacts by meteorological conditions, aerosol type, and cloud type.

Needed Products:

- MODIS, CALIPSO, CloudSat

Known Issues:

- N/A

Recent Publications:

- Zhao, B., Wang, Y., Gu, Y., et al., 2019: Ice nucleation by aerosols from anthropogenic pollution. *Nature Geoscience*, DOI 10.1038/s41561-019-0389-4, 2019.

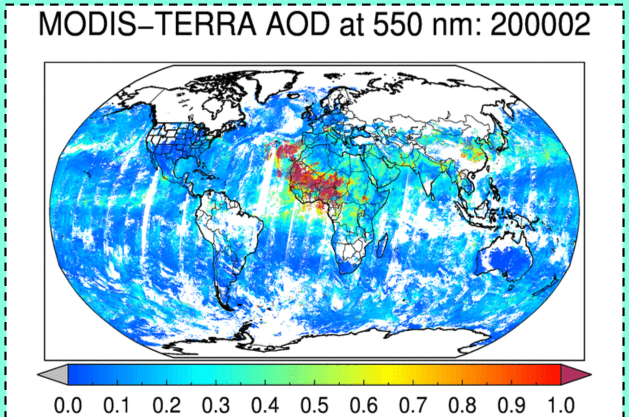
Aerosol-cloud-precipitation interactions remain one of the largest uncertainties in climate simulation and projection. In particular, the impact of aerosols on precipitation is highly uncertain due to limited and conflicting observational evidence. A major challenge is to distinguish the effects of different types of aerosols on precipitation associated with deep convective clouds, which produces most of the precipitation in East Asia. For this research, we utilized collocated satellite retrievals of aerosol and cloud properties from MODIS, CloudSat, CALIPSO, and precipitation data from the Tropical Rainfall Measuring Mission (TRMM) to explore the impacts of different types of aerosols on the precipitation frequency and precipitation amount in East Asia.

Biomass Burning and Air Quality over Indian Sub-Continent

Pawan Gupta (STI/USRA/MSFC), Robert Levy (GSFC), Anton Darmenov (GSFC)
Falguni Patadia (USRA), Lorraine Remer (UMBC/GSFC), and Krishna P. Vadrevu (MSFC)

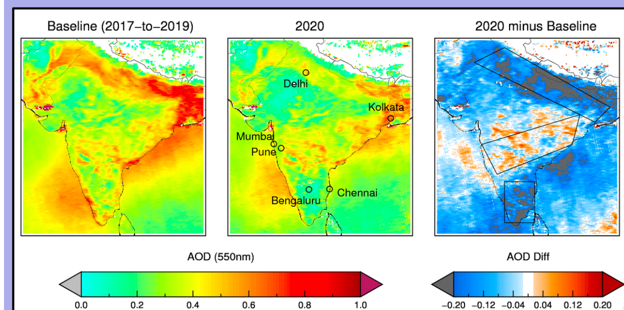
Objectives: Characterizing Nearly Two Decades of Biomass Burning Over The Indian Sub-Continent Using Satellite, Surface and Model Simulations

High Resolution Level 3 Gridded Aerosols and Fire



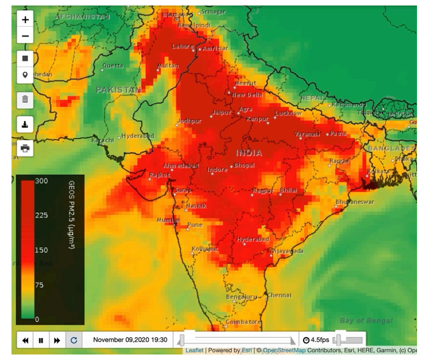
- 0.1° gridded AOD and fire counts for two MODIS generated for the entire mission life and made available;
- Data utilized to understand long-term trends in aerosols and fires in the region;
- Several independent researchers using data
- Gupta, P.; Remer, L.A.; Patadia, F.; Levy, R.C.; Christopher, S.A. High-Resolution Gridded Level 3 Aerosol Optical Depth Data from MODIS. *Remote Sens.*, 2020.

Impact of COVID-19 Lockdown on Air Quality



- high-resolution gridded AOD data were used to quantify the impact of lockdown over India and other parts of the world.
- A decrease of 4-56% in AOD was observed at local and regional scales in India during the lockdown period.
- Sathe, Gupta, et al., 2020 – under review.
- earthobservatory.nasa.gov/images/146596/airborne-particle-levels-plummet-in-northern-india
- -Yasunari et al., 2020, AGU Fall Meeting

Near Real-Time Air Quality Monitoring and Forecasting

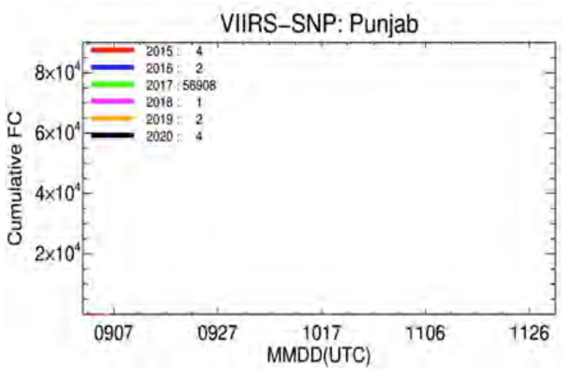


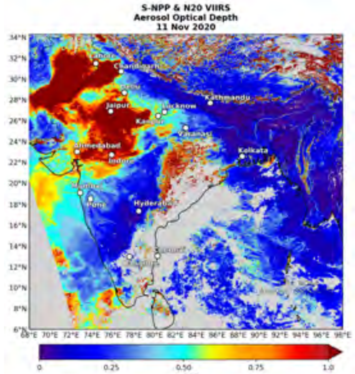
- NASA GEOS aerosol and meteorological forecasts are being used in an ML algorithm to produce regional bias-corrected AQ forecasts.
- The forecast are visualized with real-time validation using ground data. A similar system is implemented in Thailand.
- The forecasting webapp is developed in partnership with NASA-SERVIR program.

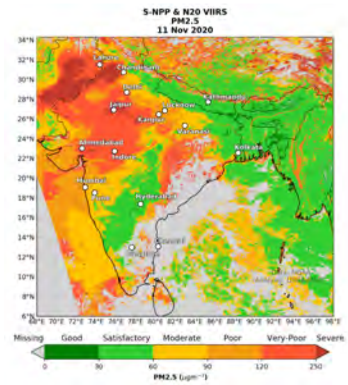
https://tethys.servirglobal.net/apps/aqx-india/

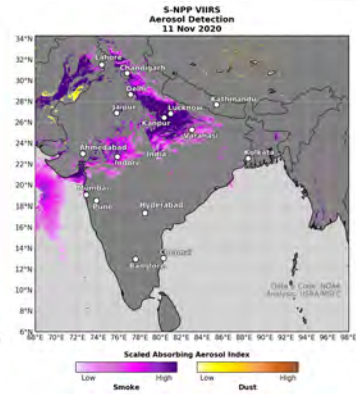
2020 Post Monsoon Fire Season and A Community Response Forum

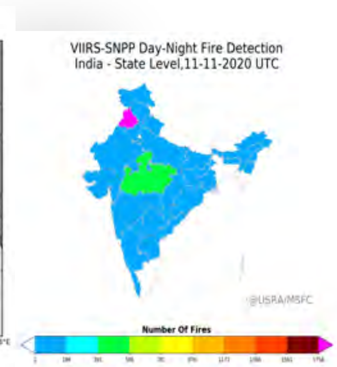
Gupta et al.











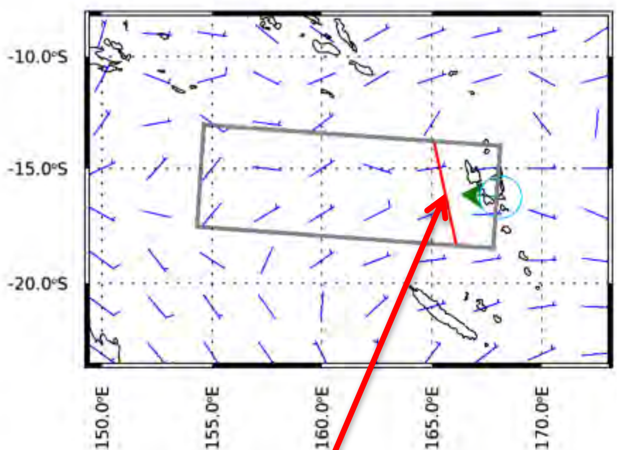
- Near real-time data products and analysis are being generated to support this year's post-monsoon fire season dominated by crop residue burning in northern India.
- This year the fire season started earlier than expected and on track to become one of the anomalous years (similar to 2016) in the nine years of VIIRS data records.
- Fire detection and aerosol retrievals from VIIRS-SNPP and NOAA-20 are being primarily used for the analysis.
- Amazon Cloud Services (AWS) are being used for data processing, and a website is created to share data and analysis with the user community (www.firesandaq2020.info)
- Data sets and analyses are also posted on SM and used by many universities, research institutions, World Bank, and media (print, tv, electronic).
- NRT aerosol data are provided by NOAA and AQ visualization by NASA's SERVIR program.

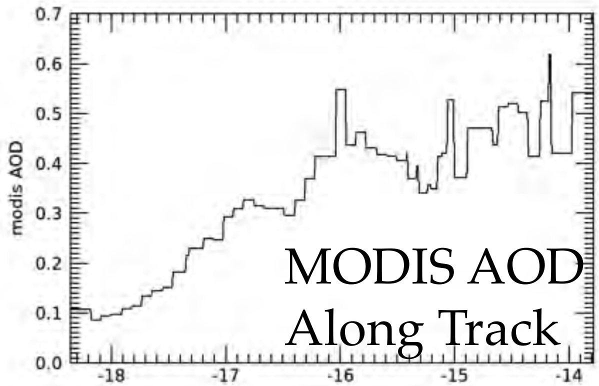
Community Response Forum

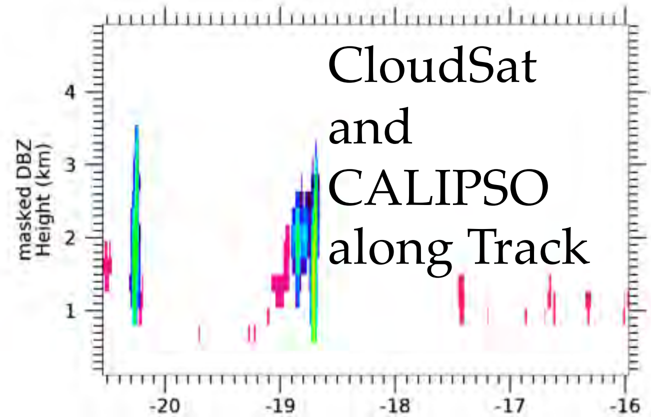
- A community response forum is being organized every Thursday since the start of the fire season, with a total of 350 active registration.
- The forum is attended by, on average, 50 participants from research, academia, govt., media, advocacy, and other groups.
- Online forum meeting consists of a weekly update on the fire activities by our team and others from the community, and invited talks on topics related to fires and air quality in the region.

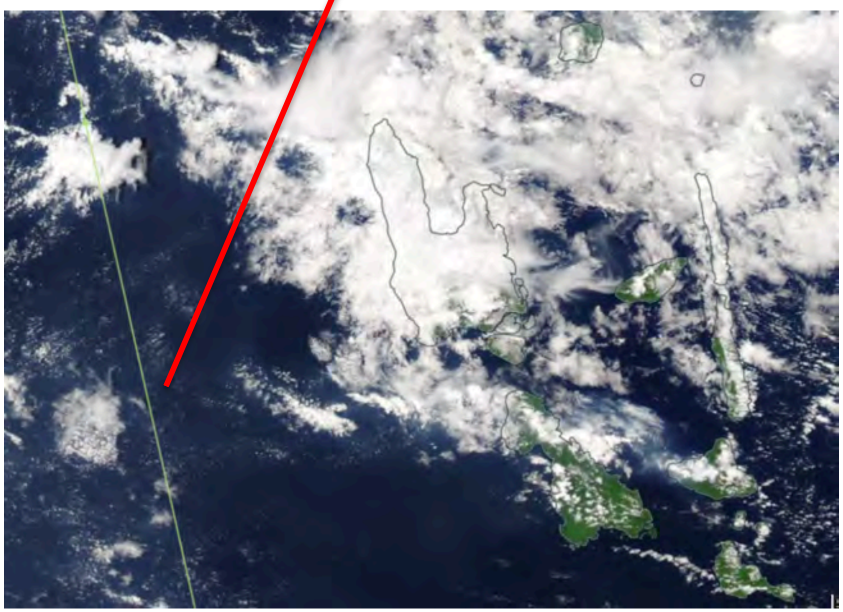
Investigating the influence of volcanic sulfate aerosol on cloud properties using MODIS data along A-Train tracks

Jay Mace and Sally Benson









Ambrym, 2010/10/28

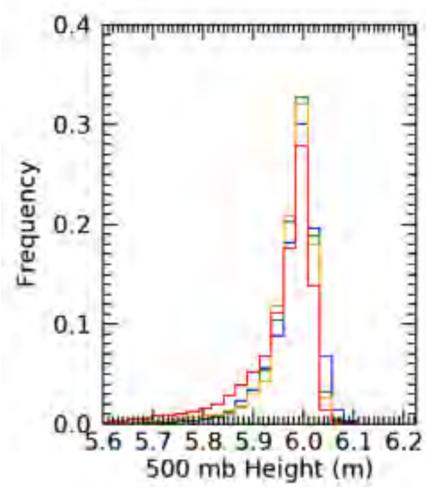
Objectives: What are the effect of volcanic sulfate aerosol on low cloud cloud properties (macro and microphysical) downstream of active marine volcanoes?

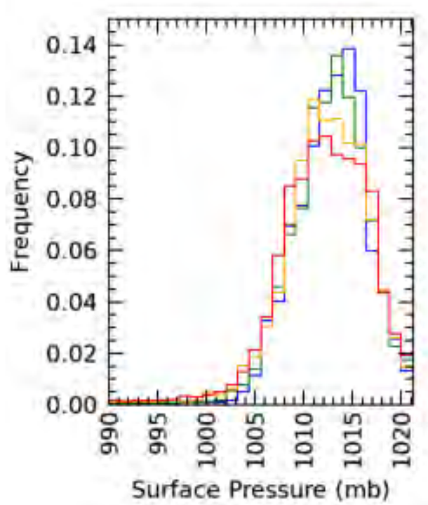
- Insight (Mace and Abernathy, 2016): Because volcanoes erupt episodically in a manner not correlated with the atmosphere, looking at cloud properties in the *downstream plume* minimizes the impact of meteorology and island effect
- Examine 4 years (2007-2010) of A-Train data from 4 volcanoes (**Kilauea, Ambrym, Nishinoshima, Heard Island**

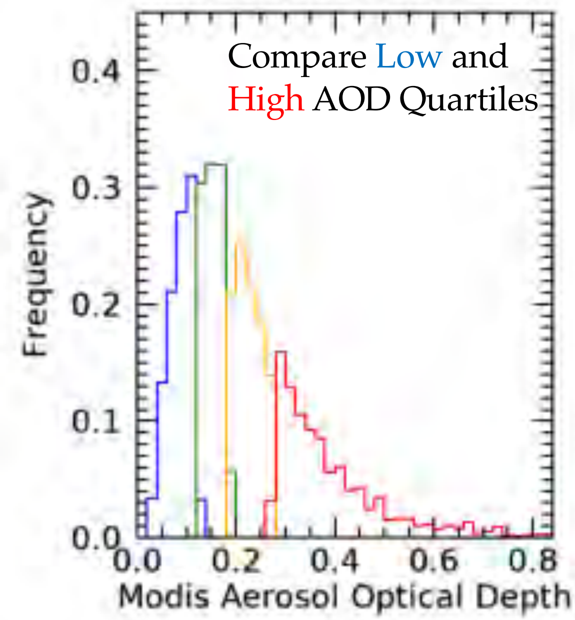
Investigating the influence of volcanic sulfate aerosol on cloud properties using MODIS data along A-Train tracks

Jay Mace and Sally Benson

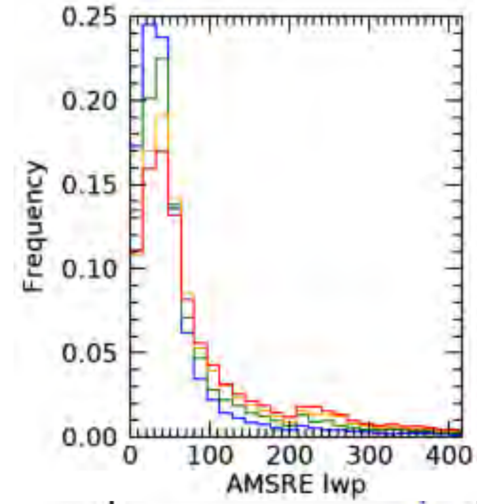
Meteorology is Identical

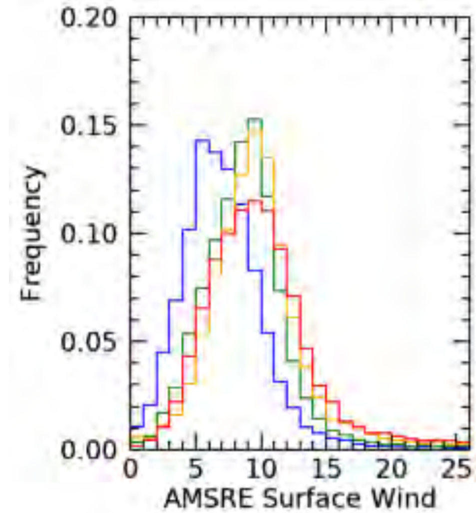




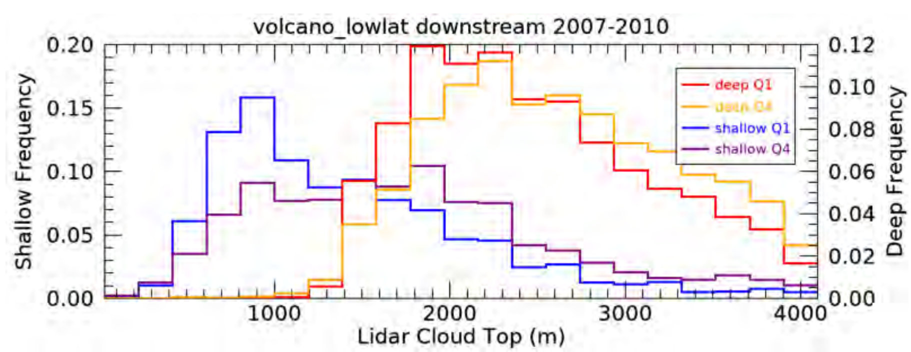


Water Path and Surface Winds both Stronger for High



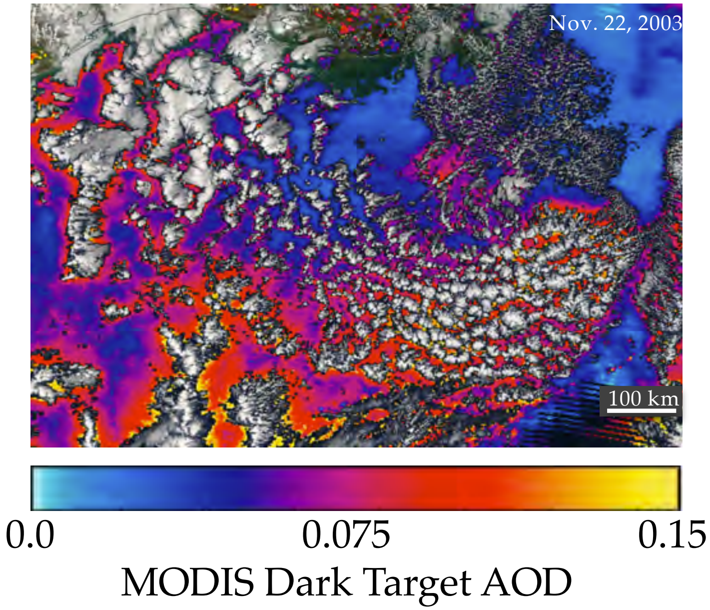


Clouds Are Deeper for High



Aerosol Properties in Partly Cloudy Regions

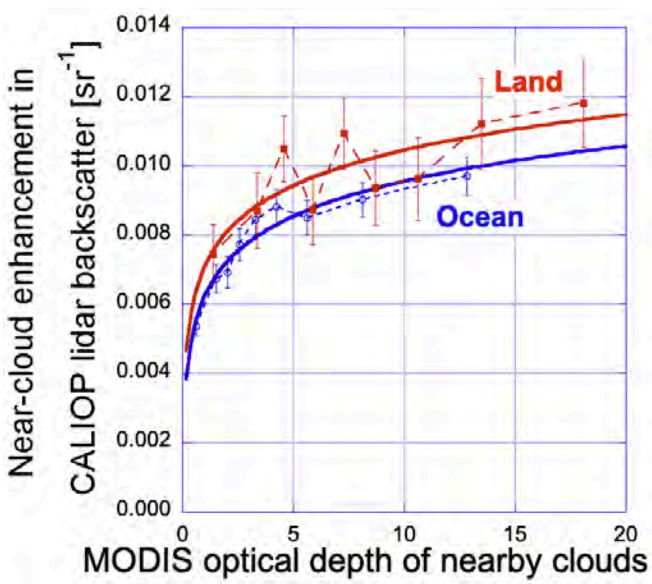
Tamás Várnai, Alexander Marshak, Robert Levy, Guoyong Wen



Objectives:

Advance our understanding on the effect of clouds and cloud-related processes on aerosol properties and aerosol radiative forcing.

Improve the interpretation of MODIS and VIIRS aerosol observations near clouds through a correction model accounting for the adjacency effect of clouds.



The top left figure illustrates near-cloud enhancements in MODIS Dark Target aerosol optical depth (AOD) over the Gulf of Mexico.

The bottom left figure shows global statistics indicating that near-cloud enhancements are stronger near thicker clouds. This tendency—combined with broken clouds being about twice as thick over land as over ocean—explains why near-cloud enhancements are about 70% stronger over land than over ocean.

Aerosol Properties in Partly Cloudy Regions

Tamás Várnai, Alexander Marshak, Robert Levy, Guoyong Wen

Status and Updates:

- Statistical data analysis is ongoing
- Reflectance correction for 3D effects has been expanded to widen coverage & accuracy

Needed Products:

- Level 1B, Level 2 aerosol & cloud products

Known Issues:

- N/A.

Recent Publications:

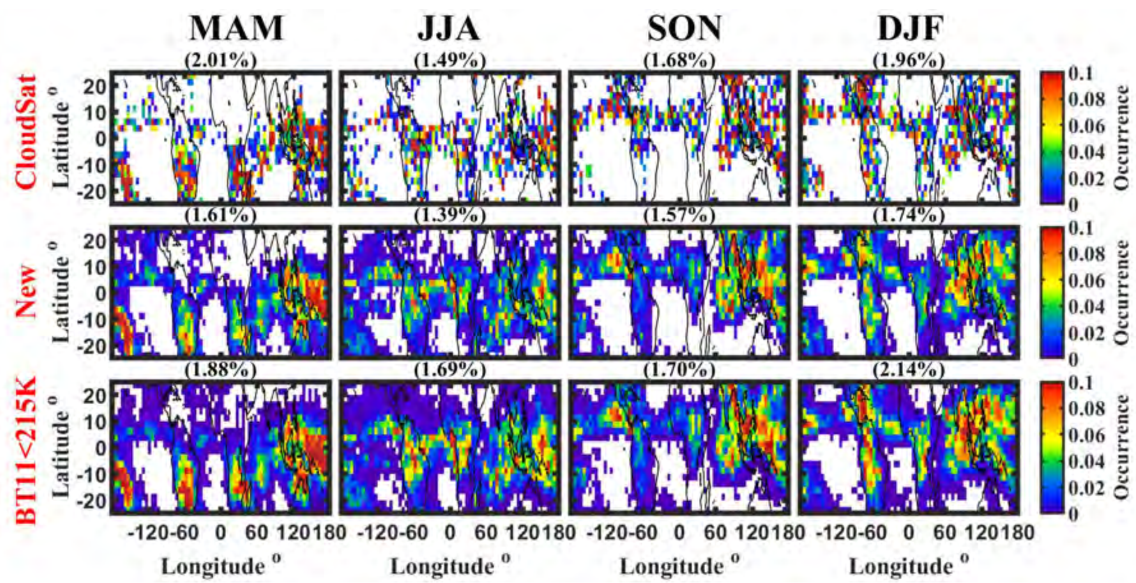
Várnai, T., and A. Marshak: Satellite observations of near-cloud changes in atmospheric aerosols. *Remote Sensing*, to be submitted in late 2020.

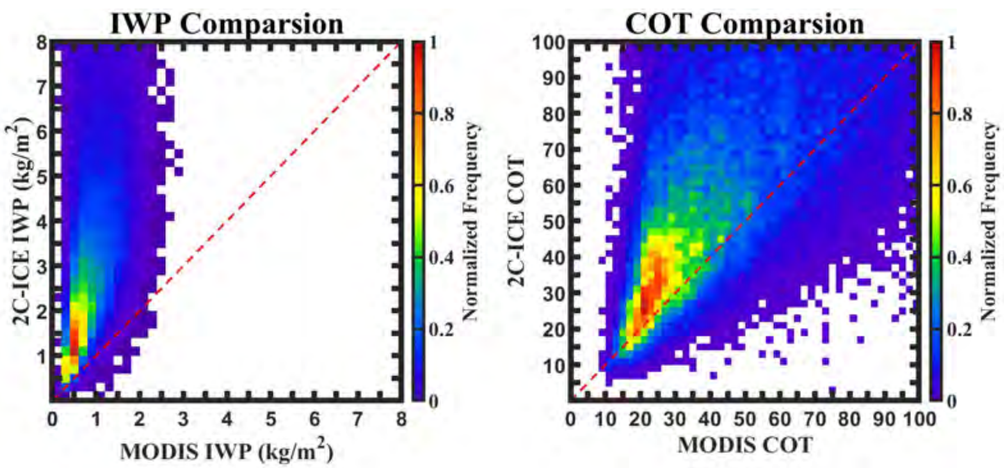
Analyze MODIS/VIIRS observations to help improve aerosol retrievals in partly cloudy regions and to better understand a topic that was described in Chapter 7 of the IPCC AR5 as follows:

"… aerosol measured in the vicinity of clouds is significantly different than it would be were the cloud field … not present." Thus *"ascribing changes in cloud properties to changes in the aerosol remains a fundamental challenge."*

Understanding the Seasonal and Interannual Variations of Tropical Convective Cloud Systems with Multi-Satellite Data Fusion: Zhien Wang, Kang Yang, and Min Deng

Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**





Synergizing MODIS and CloudSat/CALIPSO to improve the characterization of deep convective clouds.

Objectives:

1. Characterize tropical convective cloud system properties and environmental conditions.
2. Document potential sampling biases in the A-train satellite cloud measurements.
3. Understand the seasonal and interannual variations of tropical convective cloud systems.

Understanding the Seasonal and Interannual Variations of Tropical Convective Cloud Systems with Multi-Satellite Data Fusion: Zhien Wang, Kang Yang, and Min Deng

Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**

Status and Updates:

- A MODIS-based deep convective core identification algorithm is developed.
- Working on multi-year and multi-satellite dataset development for tropical deep convective clouds.

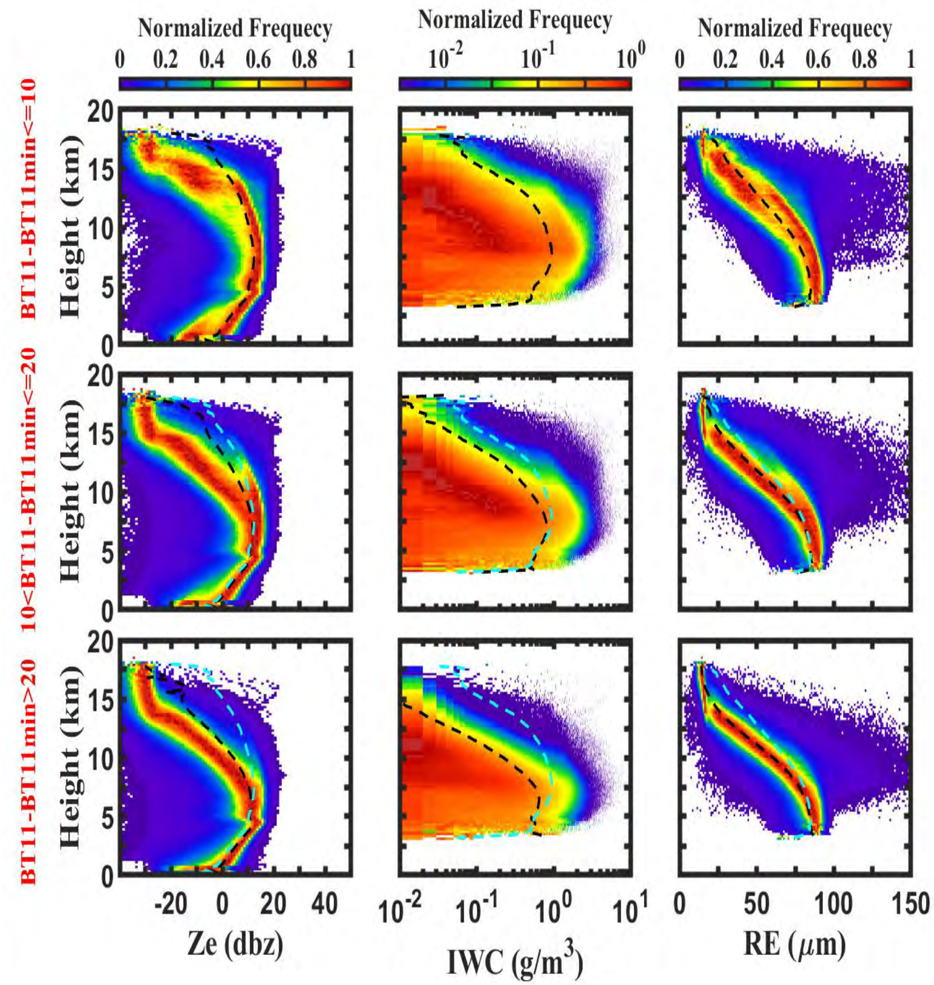
Needed Products:

- MODIS L1B
- MODIS L2 cloud properties

Known Issues:

- N/A

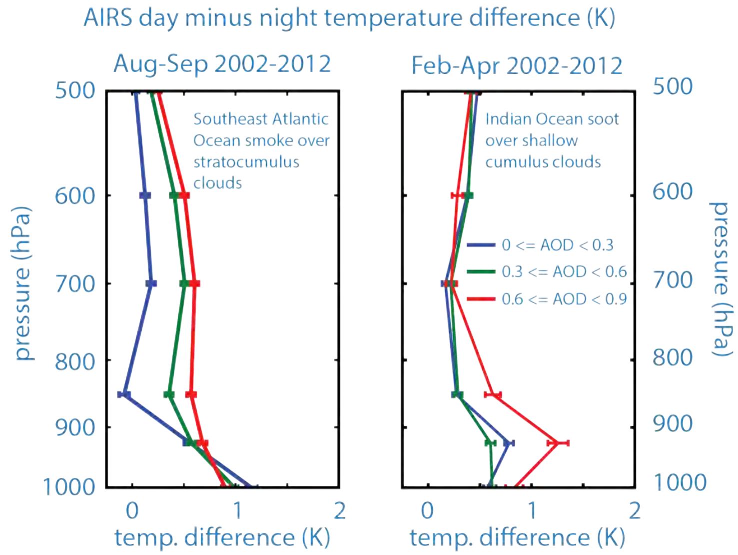
Recent Publications: two manuscripts in preparation

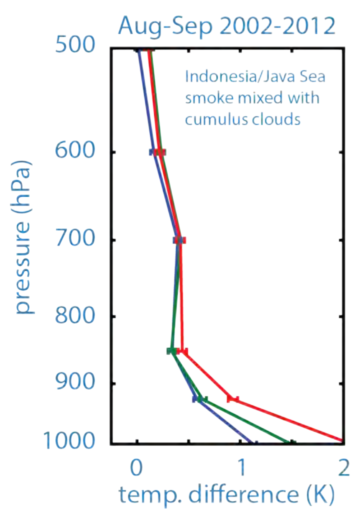


Deep convective cloud vertical structures (CloudSat/CALIPSO) in the context of storm horizontal structures (MODIS).

A Study of Atmospheric Heating by Black Carbon Aerosols and its Impacts

Eric Wilcox and Marco Giordano, Division of Atmospheric Sciences, Desert Research Institute, Reno, NV
Jun Wang and Xiaoguang Xu, Department of Chemical and Biochemical Engineering, University of Iowa





Current global observations do not discriminate light-absorbing aerosols from other species. Examination of the diurnal variability of air temperature, when sorted by aerosol optical depth (AOD), can quantify the net effect of absorption of sunlight by light-absorbing aerosol species like smoke and soot.

Objectives

- Evaluate the vertical profile of day/night air temperature contrast as a viable diagnostic for black carbon (BC) radiative heating.
- Characterize low cloud responses to variations in that BC aerosol heating.
- Broad quantification of these responses across the global tropics and subtropics.
- Supporting analyses of in-situ observations and modeling of radiative transfer and clouds.

A Study of Atmospheric Heating by Black Carbon Aerosols and its Impacts

Eric Wilcox and Marco Giordano, Division of Atmospheric Sciences, Desert Research Institute, Reno, NV
Jun Wang and Xiaoguang Xu, Department of Chemical and Biochemical Engineering, University of Iowa

Status and Updates:

- Robust signal of BC aerosols in AIRS temperature broadly identified.
- Seeking verification with in-situ observations and radiative transfer modeling.
- Quantifying cloud responses with AMSR-E, MODIS and CALIPSO cloud products.

Needed Products:

- AIRS temperature profiles
- MODIS AOD, cloud-top properties
- AMSR-E cloud water path
- CALIPSO cloud layer detection

Known Issues:

- N/A

Recent Publications:

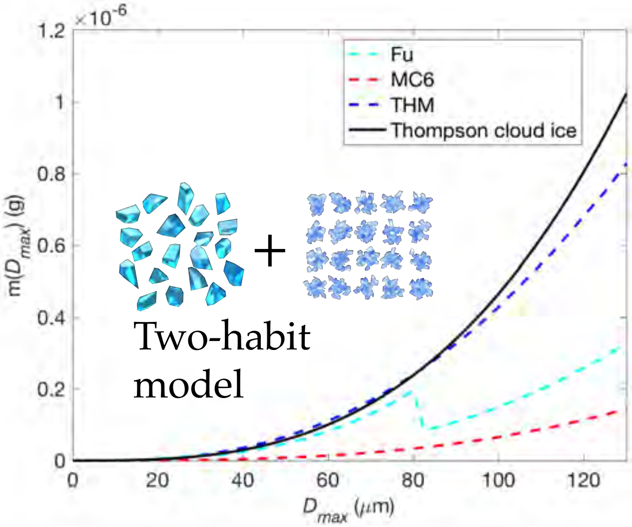
Xu, X., Wang, J., Zeng, J., Hou, W., Meyer, K.G., Platnick, S.E. and Wilcox, E.M., 2018. A pilot study of shortwave spectral fingerprints of smoke aerosols above liquid clouds. *JQSRT*, *221*.

MODIS is crucial to constraining the aerosol variations in this study. The application of newer aerosol-over-cloud retrievals can better discriminate cases where BC aerosol heating is important for cloud responses.

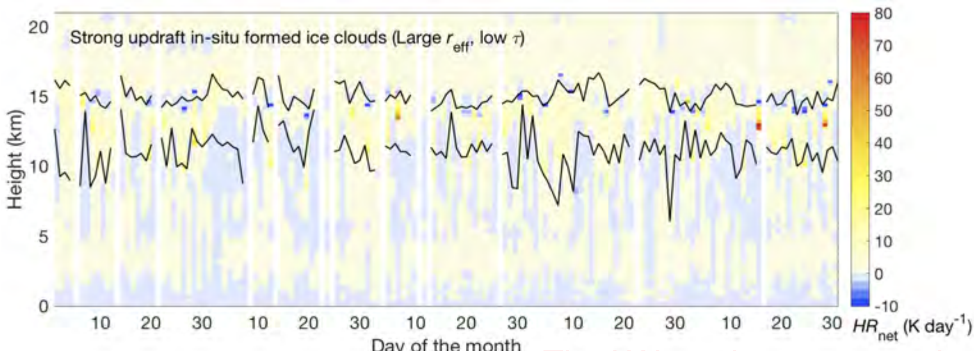
MODIS cloud property retrievals (liquid water path, particle effective radius) are important for characterizing cloud responses to BC aerosol heating.

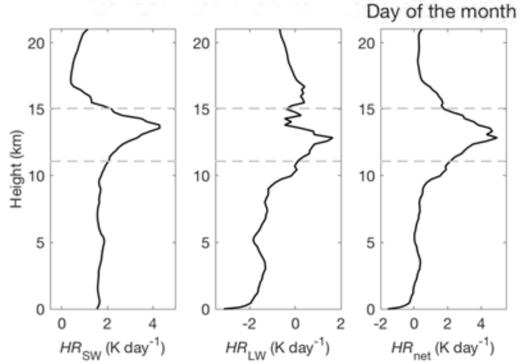
Consistency of Ice Cloud Models in Forward Retrieval and Radiative Forcing Assessment

Ping Yang (PI), Tong Ren (team member, postdoc), Texas A&M University
Non-funded collaborator: Norman Loeb, NASA Langley Research Center



Mass-dimension relations of the hexagonal column (Fu 1996), Moderate Resolution Imaging Spectroradiometer Collection 6 (MC6; Platnick et al 2017), and two-habit model (THM; Loeb et al 2018) ice cloud schemes and the cloud ice in the Thompson scheme for $D_{max} \leq 130$ μm.





The LW cooling near cloud top is dominated by the strong upper portion in-cloud SW heating, leading us to speculate that daytime ice clouds are more readily to thin out while nighttime ice clouds are more sustained.

Consistency hypothesis: Radiative fluxes derived using a consistent ice particle model assumption throughout provide a more robust reference for climate model evaluation (Leob et al. 2018).

Background of the selected study area: Cloud shortwave (SW) and longwave (LW) radiative effects at the top of the atmosphere (TOA) approximately cancel each other over cloudy regions associated with tropical deep convection. Previous studies proposed theories on whether the cancellation of cloud SW and LW radiative effects is merely a coincidence or due to some negative feedback mechanisms that maintain the near-zero balance. However, general circulation models (GCMs) show disagreeing simulated net (SW + LW) cloud radiative effects (CREs) over tropical deep convection regions.

Objectives:

- Use a combination of active and passive satellite cloud property retrievals to study the sensitivity of radiation flux calculations to ice cloud parameterization over the equatorial western Pacific Ocean region.
- Investigate the sensitivity of CREs to three ice cloud parameterization schemes in different ice cloud regimes defined in terms of cloud optical thickness and cloud top temperature.
- Study the sensitivity of radiative heating and cooling rates to the three ice parameterization schemes in different mechanism-based ice cloud regimes.

Consistency of Ice Cloud Models in Forward Retrieval and Radiative Forcing Assessment

Ping Yang (PI), Tong Ren (team member, postdoc), Texas A&M University
Non-funded collaborator: Norman Loeb, NASA Langley Research Center

Status and Updates:

- Performed radiation calculations;
- Analyzed the results;
- Writing a paper.

Needed Products:

- The A-Train integrated Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO), CloudSat, Clouds and the Earth's Radiant Energy System (CERES), and Moderate Resolution Imaging Spectroradiometer (MODIS) merged product (CCCM) Edition B1

Known Issues:

- N/A.

Recent Publications:

- Ren T., P. Yang, et al. (2020), Sensitivity of radiation flux estimations to ice cloud parameterization over the equatorial western Pacific Ocean region, *In preparation*.

- Most cloud groups have tops above 210 K and the effective radii increase with optical thickness but decrease with height.
- The hexagonal ice crystal-based scheme has the weakest SW CRE and strongest LW CRE among the three considered parameterizations.
- Identify three high ice cloud types using a mechanism-based Gaussian mixture clustering.
- Demonstrate that strong SW heating in the upper portion of the cloud layer dominates cloud top LW cooling under the daytime conditions.
- Suggest that the in-cloud radiative heating/cooling gradient could be more significant at nighttime.

Dust Variability and Direct Radiative Effect

PI: Hongbin Yu, Co-Is: Zhibo Zhang, Tianle Yuan, Robert Levy

Status and Updates:

- A climatology of dust optical depth has been derived separately from MODIS and CALIOP aerosol products.
- The MODIS and CALIOP dust optical depth climatology has been used to: (1) examine dust interannual variability and trend *(Yu et al., 2020; Song et al., slide#1)* , (2) estimate dust deposition into the tropical Atlantic *(Yu et al., 2019; van der Does et al., 2020)*, and (3) evaluate global dust simulations *(Kim et al., 2019; Wu et al., 2020)*
- MODIS AOD and FMF, along with CALIOP aerosol profile, have been used to characterize the historic dust intrusion into the Caribbean Basin in June 2020 *(paper in preparation, see right panel)*.
- Major ongoing efforts include: (a) interpreting interannual variability of African dust, (b) estimating global dust direct radiative effect (SW+LW), and (c) leading the AeroCom multi-model analysis of the Trans-Atlantic Dust Deposition (TADD).

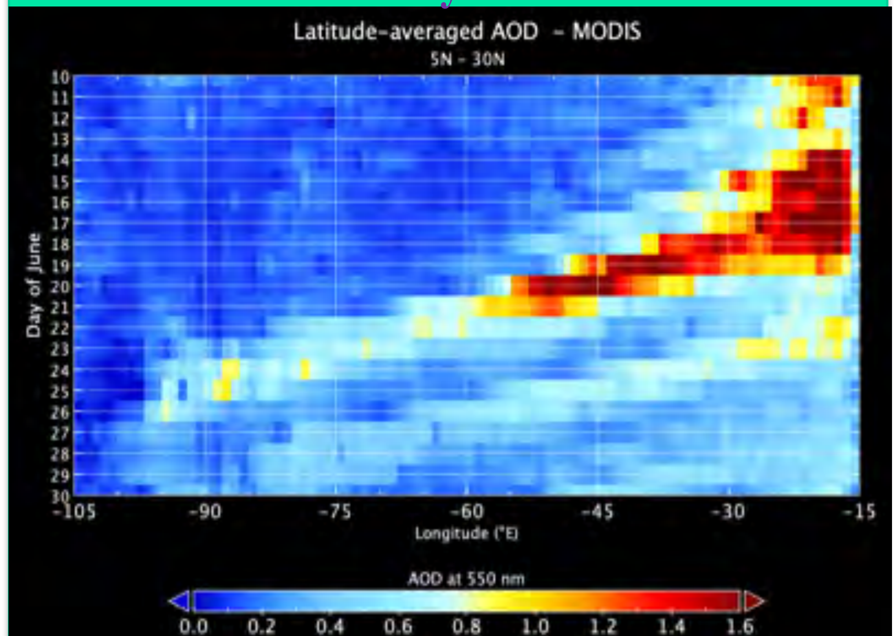
Needed Products:

- MODIS aerosol products, CALIOP aerosol profiles, global aerosol models

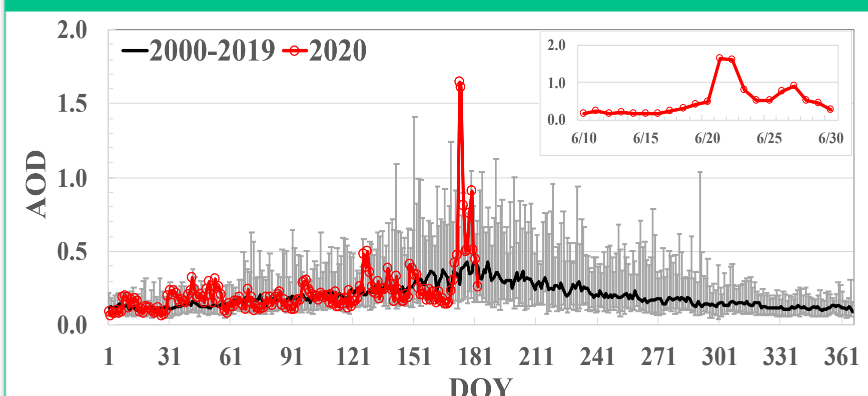
Recent Publications:

- Yu, H., et al., Interannual variability and trends of combustion aerosol and dust in major continental outflows revealed by MODIS retrievals and CAM5 simulations during 2003–2017, *Atmos. Chem, Phys., 20*, 139-161, 2020.
- Wu, M., et al., Understanding processes that control dust spatial distributions with global climate models and satellite observations, *Atmos. Chem. Phys.*, 2020, in press.
- van der Does, et al., The role of tropical rains for transport and deposition of Saharan dust across the Atlantic Ocean, *Geophys. Res. Letts., 47*, e2019GL086867, 2020.
- Yu, H., et al., Estimates of African dust deposition along the trans-Atlantic transit using the decade-long record of aerosol measurements from CALIOP, MODIS, MISR, and IASI. *J. Geophys. Res. – Atmos., 124*, 7975-7996, 2019.
- Kim, D., M. Chin, H. Yu, et al., Asian and trans-Pacific Dust: A multi-model and multi-remote sensing observation analysis, *J. Geophys. Res. – Atmos.*, 124, doi:10.1029/2019JD030822, 2019.

The Gorilla Dust Cloud (June 2020) as seen by MODIS



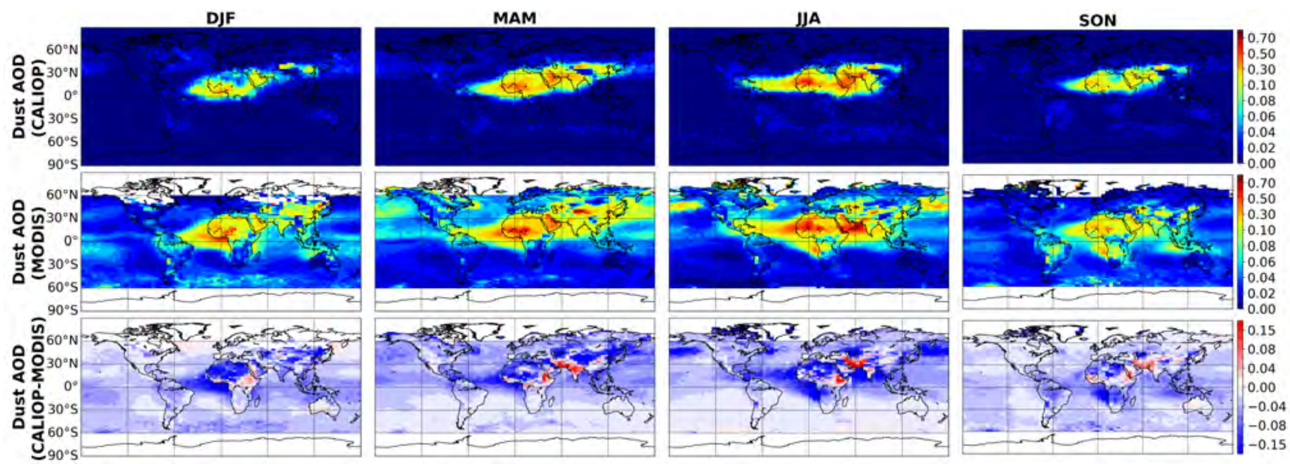
MODIS registered the event as *historic* over the last two decades



Global Dust Optical Depth Climatology Derived from MODIS and CALIOP Aerosol Retrievals on Decadal Time Scales: Regional and Interannual Variability

Qianqian Song (Student), Zhibo Zhang (Co-I), Hongbin Yu (PI), Paul Ginoux

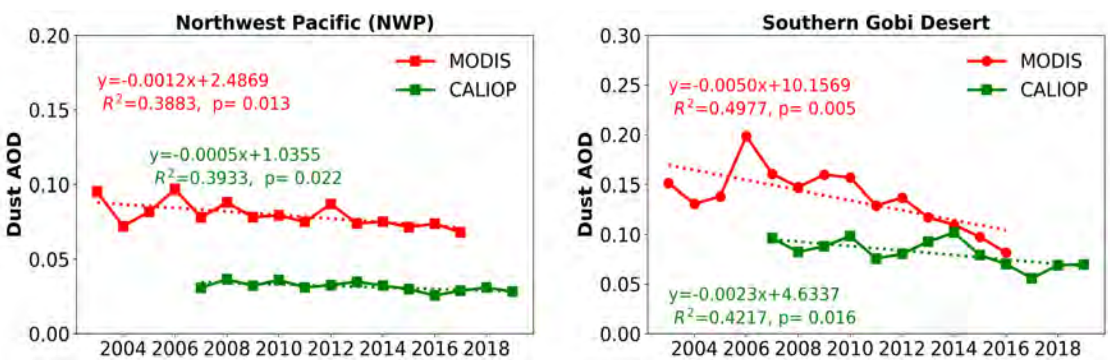
UMBC



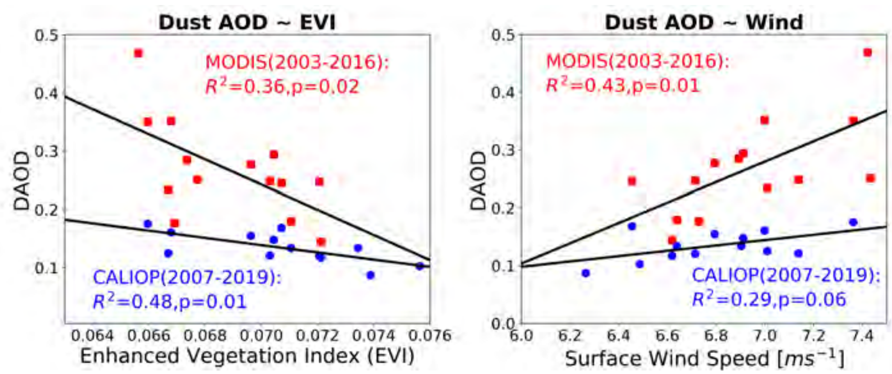
2007-2016seasonal mean DAOD climatology derived from CALIOP , MODIS and their difference.

Objectives

- Developing a decadal (2007-2019) record of global dust aerosol optical depth (DAOD) climatology based on CALIOP observations of particle shape.
- Comparing CALIOP shape-based DAOD with MODIS size-based DAOD to understand their differences in terms of global dust distribution and interannual variability.



Regional dust trend



DAOD ~ Vegetation and Wind

Key Findings:

- CALIOP captures dust signal well in dust-belt regions; CALIOP shape-based DAOD is generally smaller than MODIS size-based DAOD .
- No clear decadal trend is found in dust-laden regions except over the southern Gobi deserts and Northwest Pacific Ocean.
- The decline DAOD in the southern Gobi deserts is associated with increasing vegetation cover (as reflected by MODIS enhanced vegetation index or EVI) and decreasing near-surface wind speed.